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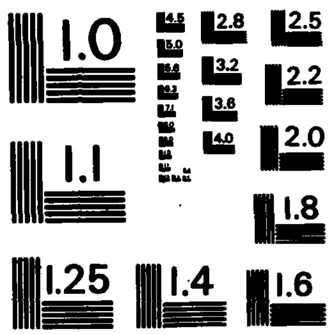

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Jerry R. Wood
Lewis Research Center
Cleveland, Ohio

Albert K. Owen and
Lawrence F. Schumann
Propulsion Laboratory
AVRADCOM Research and Technology Laboratories
Lewis Research Center
Cleveland, Ohio

National Aeronautics
and Space Administration

Scientific and Technical
Information Branch

Summary

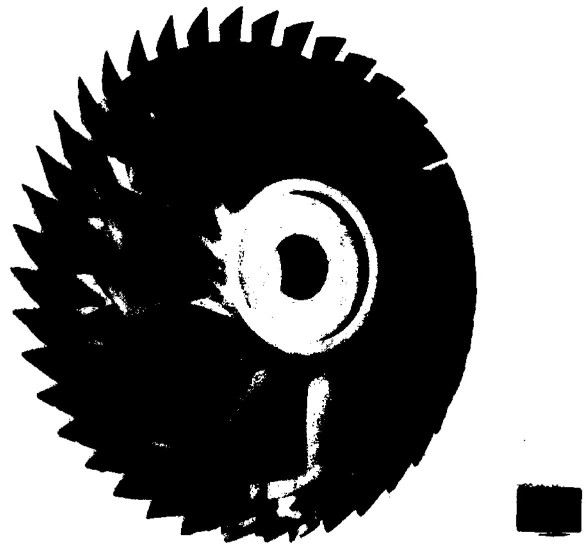
The overall and blade element data for a conical-flow compressor stage are presented. The stage was designed as the first stage of a 10:1 pressure ratio two-stage compressor. It was designed for a pressure ratio of 3.06 at a flow of 0.9072 kilogram per second. Tip speed at the inlet to the first rotor was 355.7 meters per second, and exit tip speed for the second rotor was 473.6 meters per second. The stage was tested from 50 to 100 percent of design speed from open throttle to surge. Stage performance was also taken at 90- and 100-percent speed at three values of rotor tip clearance. Peak stage efficiency at the smallest clearance (0.022 of an average radial blade height) was 0.774 at 95.8 percent of design flow and a pressure ratio of 2.613. Efficiency decreased by about 0.024 point for each 1-percent increase in average clearance over the rotors. Peak rotor efficiency at design speed from the rotor only test was 0.871 at a pressure ratio of 2.952. Survey data indicated that the hub region on both rotors was operating efficiently but that large losses were present in the outer portion of the channel.

Introduction

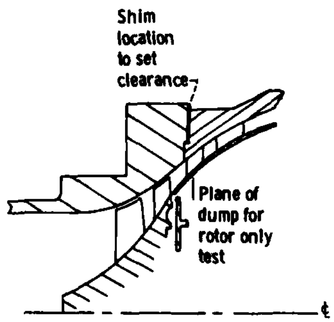
The Lewis Research Center has in the past several years been engaged in a program to investigate performance potential of small compressors (1 kilogram per second flow rate class) for gas turbine engine applications such as helicopters, auxiliary power units, general aviation, and surface vehicles (refs. 1 and 2). At high compressor pressure ratios it is necessary to use multiple stages consisting of all axial, axial/centrifugal, mixed flow/centrifugal, or centrifugal/centrifugal. As part of the small compressor program various configurations were investigated analytically under contract (ref. 3) to determine the most suitable combination of stages for an overall pressure ratio of 10:1 and a mass flow rate of 0.907 kilogram per second. A configuration consisting of a conical-flow first stage with a design pressure ratio of 3.06 and a centrifugal second stage with a design pressure ratio of 3.27 was selected as having the greatest potential to achieve good overall efficiency. The term conical flow was coined to describe a modified mixed-flow stage having axial flow type blading and an increase in radius to increase the work input potential. It was anticipated in the design process that axial compressor design criteria could be used to select blade shapes, loadings, and loss estimates and that a large static pressure rise could be obtained by increasing the radius through the blade row with little or no loss in performance from that of a purely axial blade row.

Detailed design was done for the conical-flow stage only. The stage consists of a tandem bladed rotor and a tandem bladed stator. The first blade row of the rotor has an inlet tip speed of 355.7 meters per second with a mean radius ratio (r_{exit}/r_{inlet}) of 1.23. The second blade row has a mean radius ratio of 1.15 and an exit tip speed of 473.6 meters per second. The detailed design of the stage is given in reference 3.

This report presents the overall stage performance for three values of rotor tip clearance, rotor only performance obtained without the stators, and detailed blade element data for both rotor blade rows (rotors 1 and 2). Data are presented for the stage over the stable operating range from 50 to 100 percent of design speed. Data for the rotor only test are presented for 80 to 100 percent of design speed with detailed blade element data given at 80- and 100-percent speed for both rotors. Data is given in tabular and plotted form.



(a) Tandem bladed rotor.



(b) Meridional flow path.

Figure 1. - Rotor and flow path geometry.

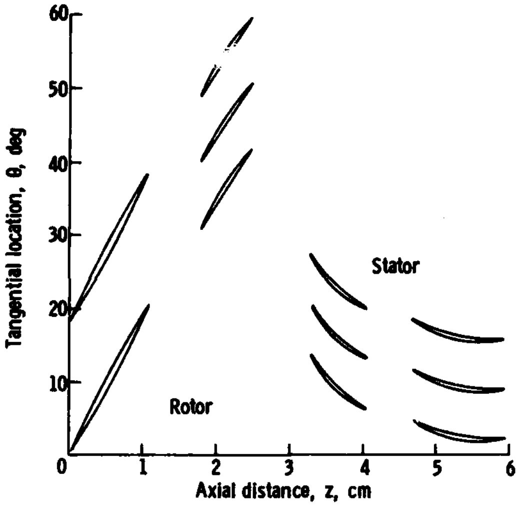


Figure 2. - Circumferential relationship of tanden rotor and tandem stator at tip section.

Shroud		Hub	
Axial distance, cm	Radius, cm	Axial distance, cm	Radius, cm
-2.531	4.597	-0.547	0.904
-1.121	4.597	----	----
[a]0	4.597	[a]0	1.285
.508	4.640	.762	1.704
1.016	4.740	1.090	1.922
[b]1.417	4.859	[b]1.417	2.196
1.783	5.020	1.925	2.728
2.148	5.210	2.179	3.033
[c]2.509	5.420	[c]2.687	3.693
[a]2.855	5.662	[a]2.855	3.909
[b]3.195	5.920	[b]3.195	4.394
3.393	6.050	3.360	4.623
3.632	6.240	3.520	4.849
[c]3.906	6.470	3.678	5.065
[a]4.272	6.789	[c]4.008	5.484
[b]4.719	7.186	[a]4.272	5.750
4.975	7.409	[b]4.719	6.281
5.227	7.62	4.996	6.561
[c]5.456	7.815	5.273	6.779
5.847	8.098	[c]5.532	7.059
[b]6.096	8.263	5.903	7.358
6.520	8.542	[b]6.096	7.506
6.944	8.771	6.515	7.813
[c]7.368	8.961	6.939	8.047
8.182	9.301	[c]7.335	8.255
9.271	10.145	8.453	8.705
↓	11.71	9.914	10.145
↓	13.65	9.914	11.71
↓	-----	9.914	13.65

[a]Survey stations.
[b]Leading edge of blade row.
[c]Trailing edge of blade row.

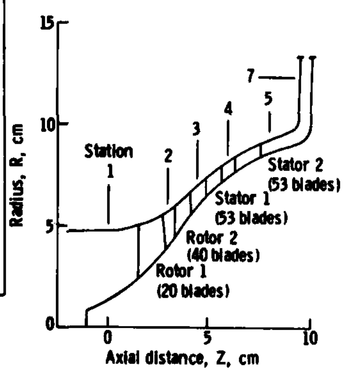


Figure 3. - Flow path geometry.

Compressor Aerodynamic Design

The detailed aerodynamic design is presented in reference 3, and, therefore, only a brief summary of the aerodynamic design parameters is presented herein. The tandem bladed rotor is shown in figure 1(a) and the meridional flow path in figure 1(b). The relationship of the tandem rotor and tandem stator blade rows to each other is shown in figure 2. The flow path geometry and instrument stations are shown in figure 3. The overall design parameters are given in table I, and design blade element data are given in table II. The stage was designed for a total pressure ratio of 3.06, a mass flow rate of 0.9072 kilogram per second, rotor inlet tip speed of 355.7 meters per second, and efficiency of 0.906. The rotor inlet relative Mach number varies from 1.256 at the tip to 0.585 at the hub. The diffusion factor for the first blade row (rotor 1) varies from 0.443 at the tip to 0.39 at the hub. The second blade row (rotor 2) diffusion factor varies from 0.493 at the tip to 0.22 at the hub. The stator inlet Mach number varies from 0.747 at the tip to 0.848 at the hub.

Some pertinent blade design parameters from reference 3 are shown in table III. Rotor 1 has 20 blades with a tip solidity of 1.34 and rotor 2 has 40 blades with a tip solidity of 1.57. Both rotors use multiple circular arc blading. The first stator row has a hub solidity of 1.891 and the second stator row has a hub solidity of 1.63. Each stator blade row has 53 blades consisting of double circular arc blading. Manufacturing coordinates are given in reference 3.

Apparatus and Procedure

Test Facility

A schematic of the compressor test facility is given in figure 4. The compressor and turbine are on a common shaft. Compressor mass flow rate was measured with a

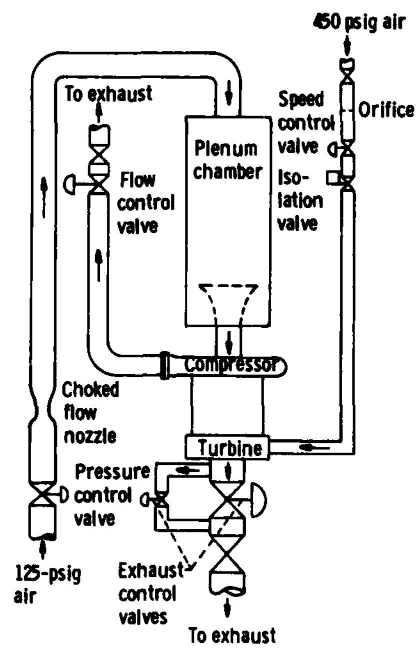


Figure 4. - Test facility schematic.

choked flow nozzle on the inlet line. Compressor inlet pressure was automatically controlled by a valve on the inlet line to the plenum chamber. Inlet temperature is not controlled but was approximately 295 K for these tests. Compressor discharge pressure was manually controlled with a remotely operated valve in the compressor discharge line. Drive turbine speed was automatically controlled by a valve on the turbine inlet line. High pressure air was used to drive the turbine. Turbine discharge pressure was manually controlled by two remotely operated valves in the turbine discharge line.

Instrumentation

The compressor instrumentation stations are shown in figure 5 and table IV and their relationship to the compressor blade rows is shown in figure 3.The flow enters the plenum as shown in figure 5, is diverted by a flow deflector, and passes through a series of screens before reaching station 0, which is used to determine compressor inlet conditions. Station 0 consists of two rakes spaced 90° apart. Each rake has four total pressure probes and two total temperature probes. The outlet measurement station for the stage (station 7) consists of

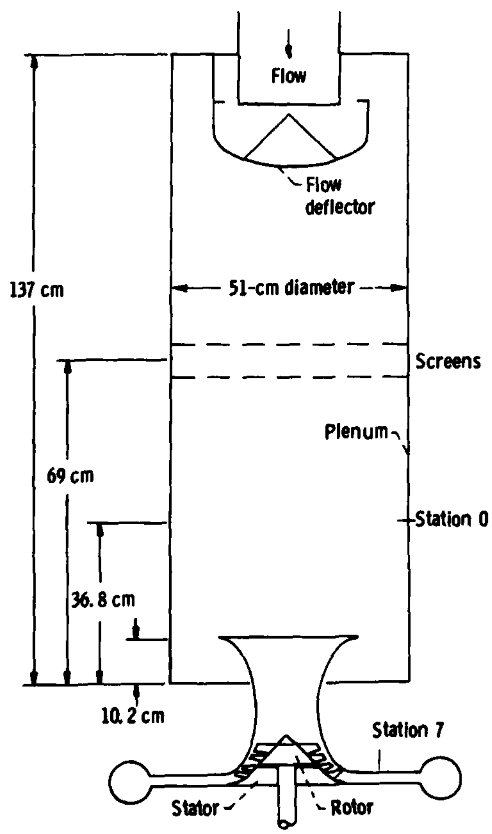


Figure 5. - Stage performance instrument stations and inlet configuration.

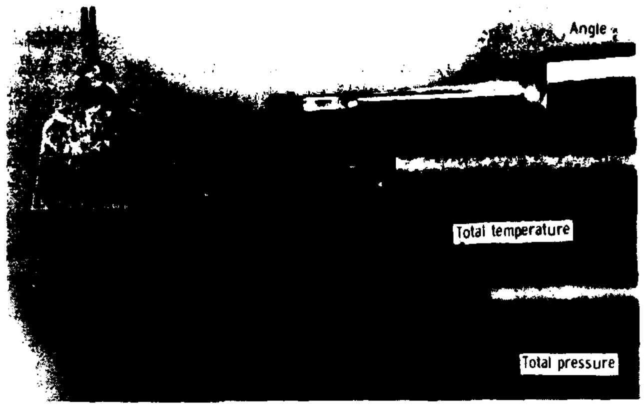


Figure 6. - Survey instrumentation.

four 0.051-centimeter-diameter total pressure probes and four calibrated high-recovery thermocouple probes located at midspan (span height, 0.643 cm). Static taps were distributed along the outer casing from station 1 to station 7 and along the hub from station 3 to station 5 (see fig. 3 for station locations and table IV for detailed instrumentation locations). Static taps spanning one stator pitch were used at station 3 (4 taps) and stations 4 and 5 (5 taps) to determine the effect of the stator vanes on static pressure.

For the rotor only tests the temperatures and pressures were measured at station 0 and total temperature was measured at station 7 using the same instrumentation as for the stage test. Static pressures were measured along the casing from station 1 to station 3.1 and on the hub at stations 3.0 and 3.1. Fast response semiconductor transducers were flush mounted over each rotor midchord to indicate rotor stall. Survey data were taken at stations 1, 2, and 3 using probes such as those shown in figure 6. Each individual thermocouple and angle probe was calibrated in a flow tunnel. The angle of the sensing element for the angle and pressure probes was made equal to the average of the hub and casing slopes at each station location.

All pressures were measured with scanivalve transducers which were dynamically calibrated during a data scan. Estimated errors in the data are as follows:

Mass flow rate, kg/sec	±0.009
Rotative speed, rpm	±50
Temperature, K	±0.6
Pressure, N/cm	±0.06

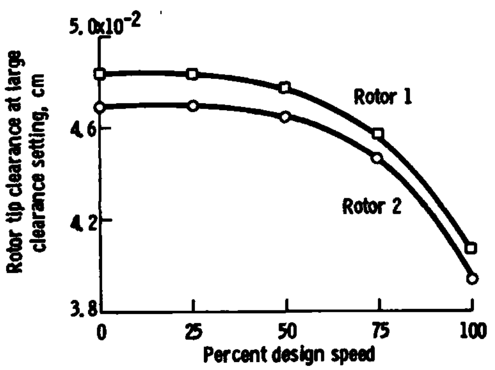
Flow angles were measured behind rotors 1 and 2 for the rotor only test. Flow angle was checked at the inlet to rotor 1 and no deviation from axial was measured. Each probe was nulled automatically to the general direction of flow and then manually nulled so that the indicated pressure differential across the side tubes was zero.

The overall accuracy of the angle measurement is probably the least accurate of the measurements considering the finite size of the angle probe (each tube was 0.038 cm in diameter) in a highly skewed flow with large pressure changes in the axial direction which would subject each side of the probe to a different static pressure.

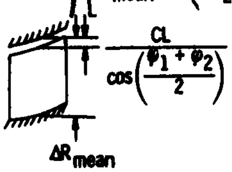
Tip clearance over each rotor was measured at four locations, 90° apart, with carbon rub probes. Probe holders for the carbon probes had been machined with the casing and provided a reference for measuring the probe length.

Test Procedure

Tip clearance.—Tip clearance was measured over the tips of both rotors. Clearance was established over the rotors by shimming the shroud axially away from the stator assembly 0.33 centimeter downstream of station 3 (see fig. 1(b)). The deflection curve measured for both rotors as a function of percent design speed is shown in



$$\text{Fractional clearance} = CL\Big/\left[\Delta R_{mean}\cos\left(\frac{\varphi_1+\varphi_2}{2}\right)\right]$$



Rotor	$\frac{\varphi_1+\varphi_2}{2}$	$\Delta R_{m,cm}$
1	26.8°	2.195
2	39.1°	1.256

Clearance setting	Design speed clearance (fractional)		Design speed clearance (CL), cm		Average fractional clearance
	Rotor 1	Rotor 2	Rotor 1	Rotor 2	
Large	0.0207	0.0404	0.0406	0.0394	0.031
Medium	.0177	.0320	.0347	.0312	.025
Small	.0160	.0273	.0314	.0266	.022

Figure 7. - Clearance curve for both rotors as function of percent speed.

figure 7. The stage test was run at three clearance settings as shown in figure 7. The smallest setting was for a clearance of 0.0314 centimeter over rotor 1 and 0.0266 centimeter over rotor 2.

Stage test.—For all tests inlet temperature was approximately 295 K and inlet pressure was approximately 9.9 newtons per square centimeter. Speed varied from 50 to 100 percent of design and flow varied from open throttle to surge. Surge was assumed to occur whenever a significant pressure fluctuation was observed in the exhaust line downstream of station 7 or an audible noise was heard in the test cell. Capacitance probes located near the back of rotor 2 indicated large rotor motion in surge. At the smallest clearance tested, the stage was not surged since open throttle running clearance was quite small.

Rotor only test.—The rotor only test was conducted by removing the stator assembly and replacing it with dummy pieces to simulate stator wall contours back to about station 3.3 (see fig. 1(b)) where the flow was dumped. The dump was used in an attempt to inhibit any rotating stall that might occur in the long, vaneless passage. The test was run at the smallest clearance quoted for the stage test. Speed was varied from 80 to 100 percent of design and the flow was varied from open throttle to surge.

Since the passages are quite small for these rotors (radial spans at stations 1, 2, and 3 are 3.312, 1.753, and 1.039 cm, respectively), only one station was surveyed at a time to minimize disturbances to the flow. Also, because of the small probe sizes desired, separate probes were used to measure flow angle, total temperature, and total pressure. Angle probes were installed at each station and angle distributions were measured for each desired operating point on the map. The test package was shutdown and the angle probes replaced with total pressure probes. The operating points were reset and the total pressure probes set according to the previously determined angle distribution. The process was repeated for the temperature measurements. Consequently, it was necessary to set the flow rate and speed of a particular operating point three different times (for measurements of flow angle, temperature, and total pressure). The repeatability which could be obtained in setting flow rate and speed for these surveys was checked on different days with the angle probe. Repeatability of the angle measurements for different test days was 1 or less.

Calculation Procedure

Overall performance.—Stage efficiency values are based on the arithmetic average of the four total pressure and total temperature values from the midspan probes at station 7 and the arithmetic average of the four total temperatures and eight total pressure values from the rakes located at station 0. These values were used to

determine actual and ideal values from tables of gas properties.

Overall rotor performance for the rotor only test is not based on measured quantities from hub to shroud but is derived from a calculated total pressure at station 3. This total pressure is calculated iteratively from the equations (symbols defined in appendix A) in appendix B using the following quantities: (1) flow path area, (2) mass flow rate, (3) measured static pressures on the hub and shroud, (4) an average tangential component of velocity obtained from the actual enthalpy rise to station 7, (5) an average wheel speed at rotor 2 exit, and (6) an assumed aerodynamic blockage of 2 percent. This value of aerodynamic blockage was arbitrarily selected in order to match the calculated total pressure result with the overall performance results from the surveys. This method of obtaining rotor performance was used since survey results were not obtained over the entire rotor map because of the large amount of time required to obtain one operating point (~ 2 hr).

Survey performance of rotor only test.—The overall results from the surveys are mass-averaged total temperature and energy-averaged total pressure. These values and the blade element data were calculated using a specific heat ratio of 1.4. Since static pressures could be measured only on the shroud at stations 1 and 2 and since it was necessary to correct the thermocouple readings for Mach number effects, the following procedure was used to obtain the static pressure gradient:

(1) The temperature was corrected assuming a constant static pressure from shroud to hub equal to the measured shroud value.

(2) This result and the measured mass flow rate from the flow nozzle were input to the computer code of reference 4.

(3) The resultant static pressure gradient from step 2 was used to correct the raw temperature readings for Mach number for subsequent input to the computer code.

Steps (2) and (3) were repeated (only about one cycle was required) until the static pressure gradient obtained did not change. In order to match the mass flow rate measured with the flow nozzle, it was necessary to reduce the flow angle distribution from hub to shroud by a constant amount (approximately 9° to 11.5° for station 2 and 7° to 9.5° for station 3 depending on the flow point). Flow angle rather than total pressure was adjusted since it was judged improbable that the pressures would be significantly in error since they were measured on scanivalves that were continuously calibrated with known high and low pressures with a port open to atmosphere for a check against barometric readings. Values of total pressure measured when the probes were retracted out of the flow stream were slightly above measured static pressures at that point indicating no leakage occurred between impact head and transducer for the total pressure measurements. All values quoted are based on the angle distribution corrected to satisfy continuity. Conditions at the survey stations were translated to the blade leading and trailing edges using the computer code of reference 4. The static pressure gradient at the leading and trailing edges obtained from the code were matched to measured shroud static pressures at the edges. The blade element data are based on the translated values of the measured quantities and the matched static pressure profiles at leading and trailing edges.

Results and Discussion

The results of this investigation are presented in three parts: overall stage performance for three values of rotor tip clearance, overall performance from the rotor only test, and blade element data for rotors 1 and 2. Overall stage performance is given in table V. Static pressures measured through the stage are given in tables VI and VII. Rotor performance for the rotor only test is given in table VIII. Static pressure ratio along the rotor shroud for the rotor only test is given in table IX. Data at each survey station are given in tables X to XII. Blade element data are given in tables XIII and XIV.

Overall Stage Performance

Overall performance for the stage at the medium clearance is shown in figure 8. Peak efficiency is fairly constant for all speed lines from 50 to 100 percent of design flow with a maximum efficiency of 0.772 at 90- and 95-percent speed. Peak efficiency at 100-percent speed is 0.767 at a pressure ratio of 2.588.

A comparison of the performance obtained with the large, medium, and small clearances is given in figures 9 and 10 for 90- and 100-percent speed. Both pressure ratio and temperature ratio increase as clearance is reduced with a corresponding increase in efficiency (fig. 9). Crossplots of peak efficiency and peak pressure ratio for each clearance at 100-percent speed are given in figure 10. Maximum efficiency and pressure ratio occur at the smallest clearance where peak efficiency was 0.774 at a pressure ratio of 2.613 at 95.8 percent of design flow. The data indicate a linear variation with clearance of both rotors with about a 0.024 change in efficiency for each 0.01 change in clearance as a percent of a mean radial span. Some of the effect due to clearance could be attributed to an area ratio change between rotor 2 exit and rotor 1 inlet which would allow more diffusion through the blade rows. The area ratio (rotor 2 exit over rotor 1 inlet) increased by 1.3 percent as clearance was increased from the smallest to the largest clearance.

The static pressure ratio through the stage at peak pressure ratio and peak efficiency for the small clearance

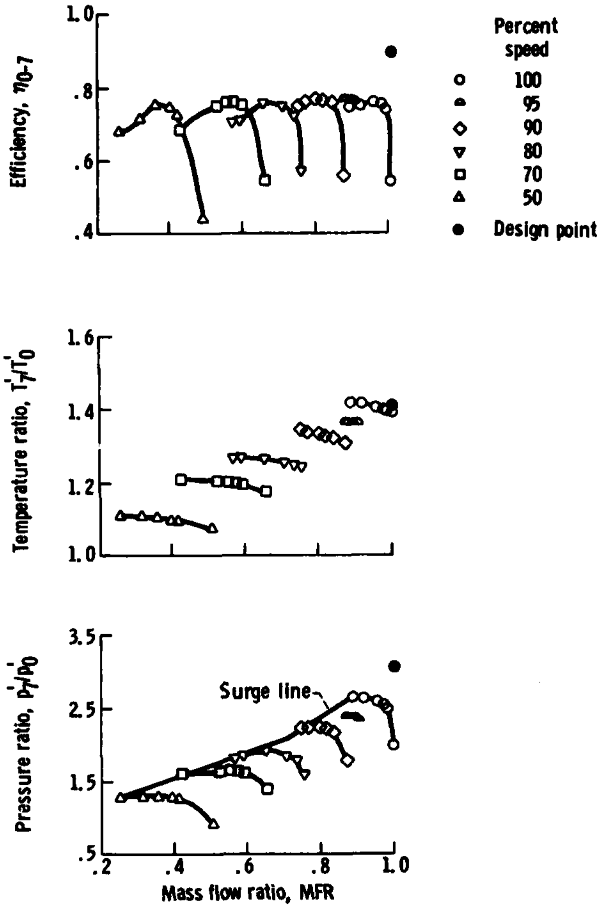


Figure 8. - Stage performance for medium clearance.

at 100-percent speed is shown in figure 11 with the design static pressure distribution. The static pressure ratio at peak efficiency at rotor 1 exit is about 6 percent lower than design and at the exit of rotor 2 it is about 13 percent lower than design. The lower than design pressure rise results in a mismatch between rotor and stator.

Static pressure ratio as a function of mass flow ratio is shown is figure 12 for the medium clearance. At the one-third axial chord position of rotor 1 for 70- and 80-percent speed the static pressure ratio initially increases as flow is decreased; however, eventually a positive pressure ratio as a function of mass flow rate characteristic occurs, indicating that the rotor is stalled or near stall. Dynamic pressure traces obtained with the rotor only test indicated rotating stall occurred in the rotor at a flow point consistent with that shown in figure 12 where the rotor pressure ratio characteristic is zero or slightly positive.

Overall Rotor Performance from Rotor Only Test

Overall rotor performance as calculated per the Calculation Procedure section is presented in figure 13. The integrated values obtained from the survey data at station 3 are also shown in the figure. The performance is referenced to plenum conditions since surveys at station 1 were not taken at all flow points. Calculated values are in good agreement with measured values. Peak pressure ratio from the survey data is 2.982 at a mass flow ratio near stall. Maximum efficiency at 100-percent speed as obtained from the survey data is 0.871 at a pressure ratio

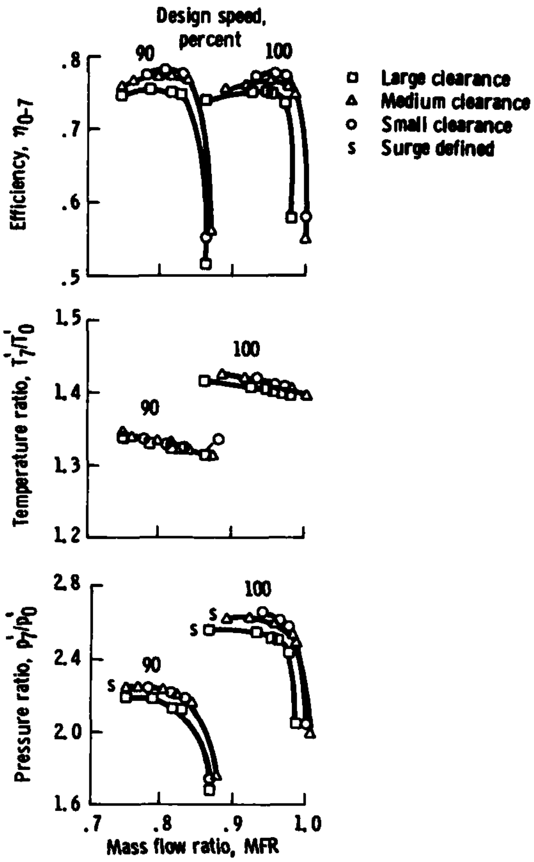


Figure 9. - Effect of radial clearance over rotor tips on stage performance at 90- and 100-percent design speed.

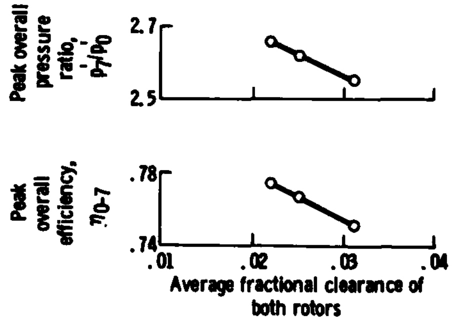


Figure 10. - Variation of peak stage efficiency and peak stage pressure ratio with radial clearance at design speed.

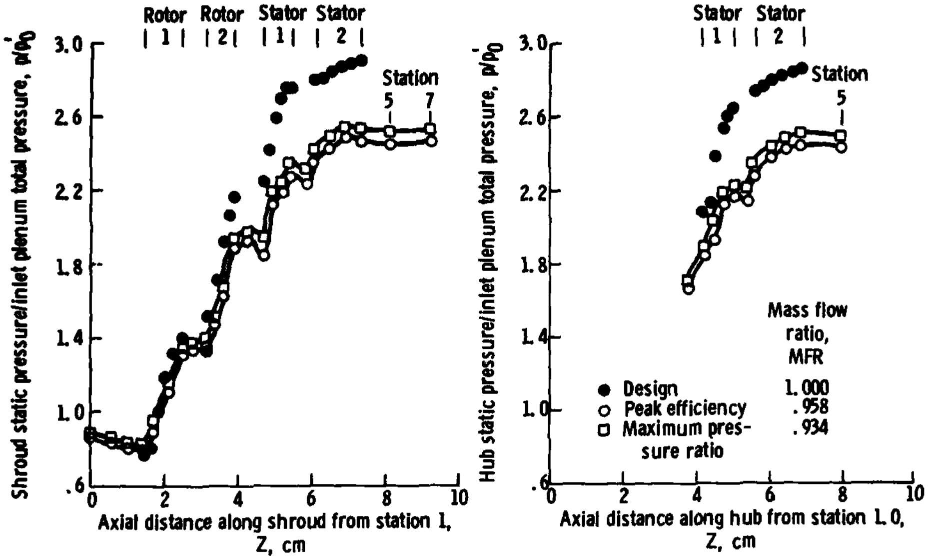


Figure 11. - Static pressure ratio distribution at 100-percent design speed for stage test at small clearance for peak efficiency and peak pressure ratio.

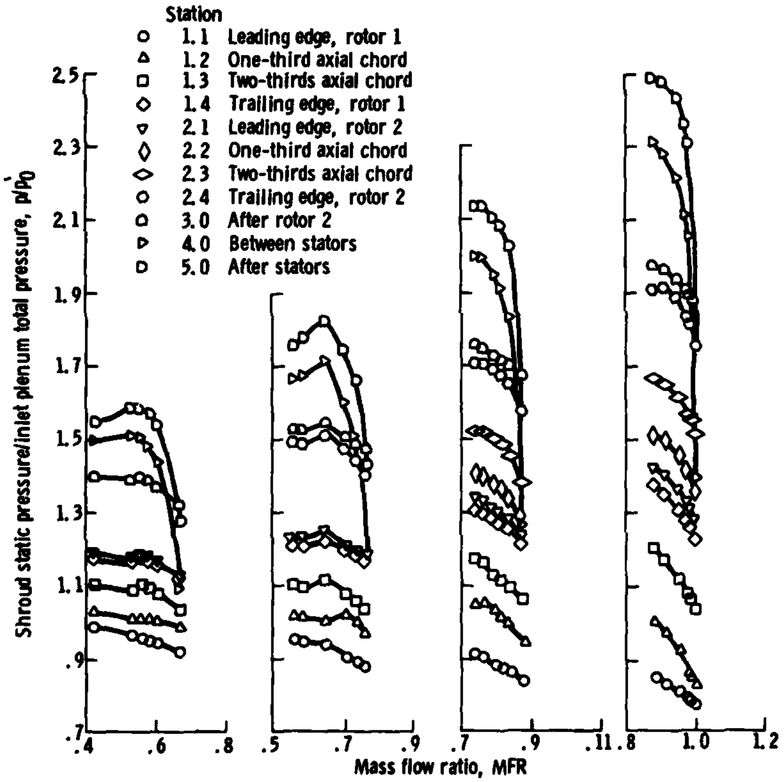


Figure 12. - Shroud static pressure ratio at various stations for medium clearance stage test.

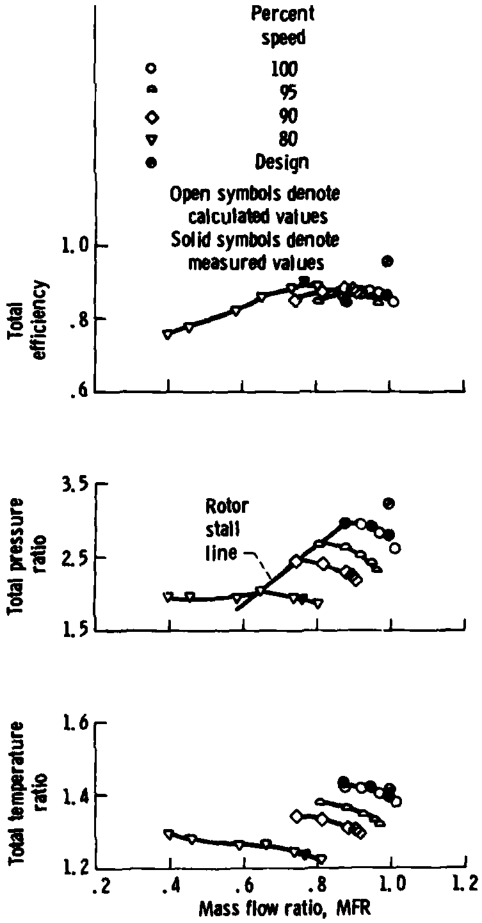


Figure 13. - Rotor performance at station 3 from rotor only test (referenced to plenum conditions).

of 2.952. The performance of the rotor referenced to station 1 is given in table VIII, part (c), and shows that peak efficiency at 100-percent speed is 0.886 at a pressure ratio of 2.971. Approximately 0.008 of the efficiency difference is attributable to the total pressure difference between stations 1 and 0 and approximately 0.007 is attributable to heat recirculation into the inlet. The rotor stall line was determined by the high-response pressure transducer located over rotor 1. Static pressure ratio along the shroud is shown in figure 14.

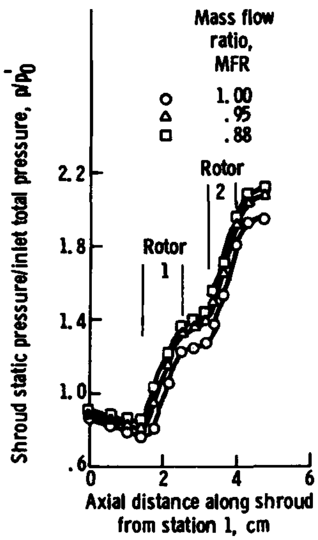


Figure 14. - Static pressure ratio distribution along shroud at small clearance for rotor only test at 100-percent speed.

Radial Distribution of Performance Parameters

The radial distribution of several parameters is presented in figures 15 and 16 for rotors 1 and 2, respectively. Data were taken at 100-percent speed at design flow, peak efficiency flow, and at a flow near stall. The distributions of pressure ratio, efficiency, diffusion factor, and total pressure loss coefficient are given for 10- to 90-percent streamlines from the hub. Design conditions for both rotors are also given.

Rotor 1

Efficiency near the hub is very high and is close to the design value from 10- to 35-percent span from the hub. It falls gradually to about 0.05 less than design at 70-percent span, and then it decreases rapidly toward the tip where it is considerably below design. The fall in efficiency near the tip is due to a large increase in temperature ratio beyond 70-percent span. This is indicative of a high loss region caused either by separation of the flow or by migration of low energy fluid toward the tip region. Pressure ratio is also high near the hub region and slightly exceeds design values. It decreases sharply to 40-percent span where it tends to remain constant.

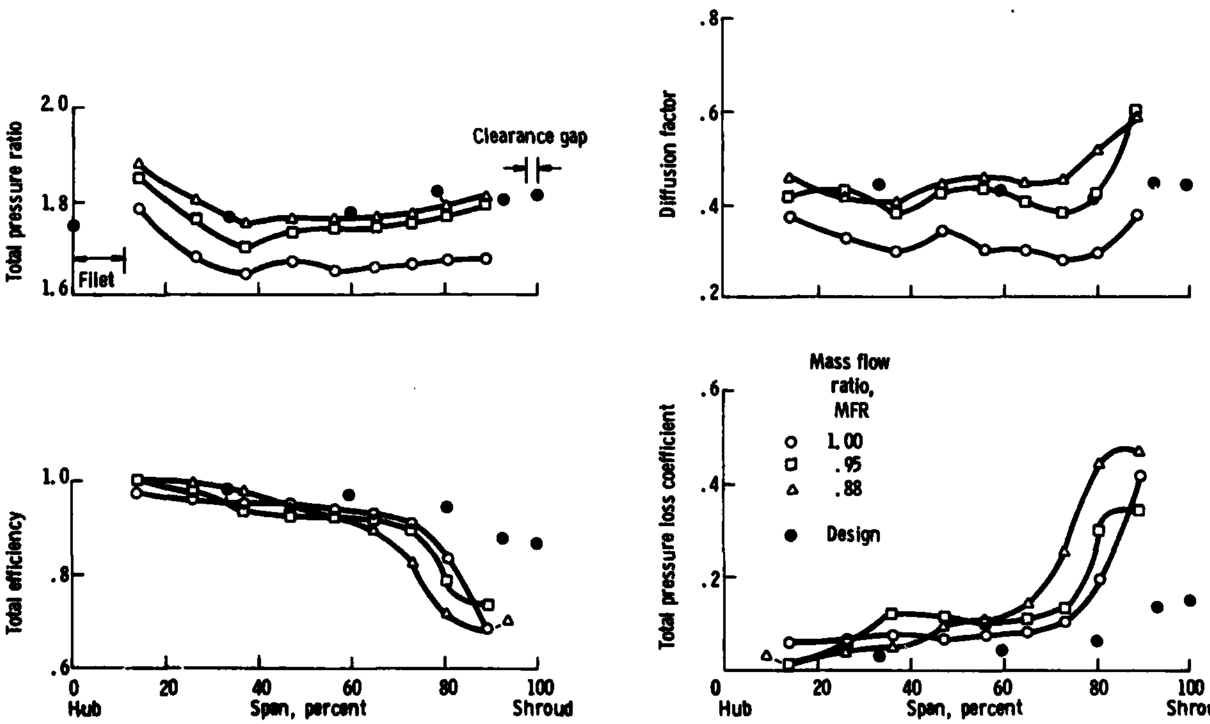


Figure 15. - Radial distribution of performance for rotor 1 at 100-percent speed.

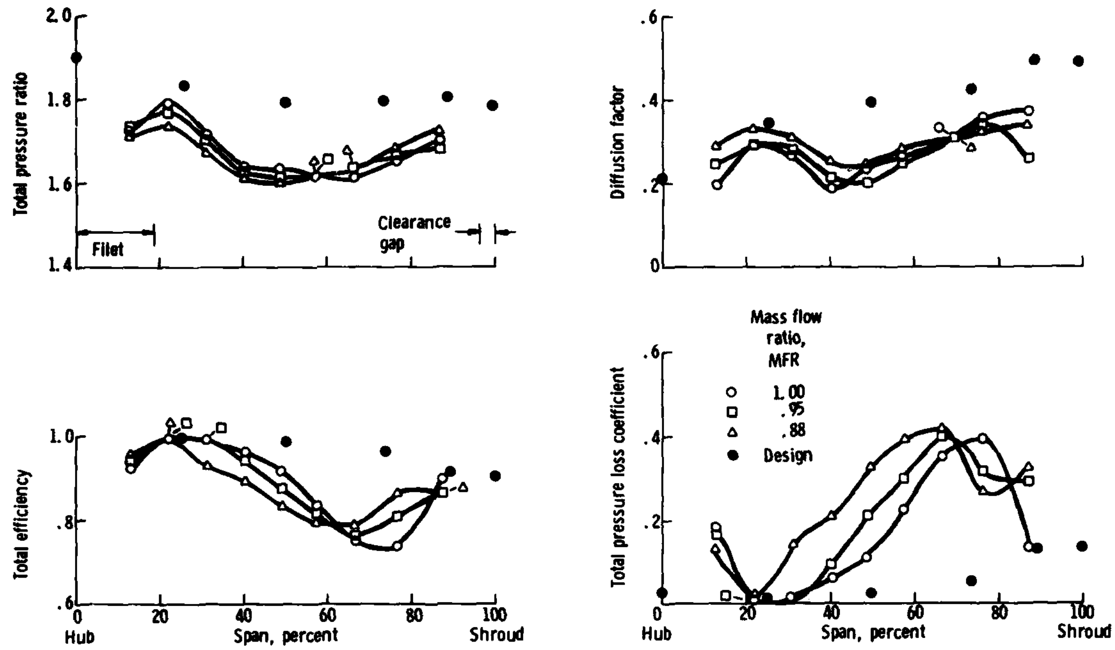


Figure 16. - Radial distribution of performance for rotor 2 at 100-percent speed.

Rotor 2

Efficiency is very close to design value from 20- to 30-percent span; however, it is significantly below design value over the rest of the span except in the near tip region. Pressure ratio is below design value over the entire span. The total pressure loss coefficient is generally higher than that for rotor 1 and much larger than the design value over most of the span.

Concluding Remarks

A conical-flow stage consisting of a tandem rotor followed by a tandem stator has been evaluated experimentally. Although the rotor performance is considerably below the design value, the performance is still quite good for this size machine. A fair assessment of the concept cannot be made since the reduced rotor pressure ratio at design flow resulted in a flow mismatch with the stator. The measured rotor performance would indicate, however, that the conical-flow concept has potential for achieving a large pressure rise in a single stage at good efficiency. A redesigned rotor based on the measured data coupled with new stator rows that are matched for flow area and incidence could produce a stage total pressure ratio of approximately 2.8:1 with an efficiency in the mid 80's at a 0.3 exit Mach number.

Summary of Results

This report has discussed the overall and blade element performance of a conical-flow compressor having a tandem rotor and tandem stator. The stage is suitable as the first stage of a high-pressure-ratio two-stage unit. The stage was designed for a pressure ratio of 3.06, first rotor inlet tip speed of 355.7 meters per second, and second rotor exit tip speed of 473.6 meters per second. Overall stage performance was taken from 50 to 100 percent of design speed. Performance at 90- and 100-percent speed for three values of rotor tip clearance was also taken. Rotor only performance was taken from 80 to 100 percent of design speed and detailed blade element data were obtained at 80- and 100-percent speed. The results are as follows:

1. At 100-percent speed the peak efficiency for the stage was 0.774 at 95.8 percent of design flow and a pressure ratio of 2.613 for the smallest clearance tested (0.022 of an average radial blade height for both rotors).
2. Peak efficiency at design speed decreased by 0.024 for every 0.01 increase in clearance as a fraction of an average radial blade height.
3. Peak rotor efficiency at design speed from the rotor only test was 0.871 at a pressure ratio of 2.952.
4. The pressure ratio developed by the rotor at design speed and design flow was significantly below the design value. This resulted in a flow mismatch between the rotor and stators.
5. In general, rotor blade element efficiency was high near the hub and dropped rapidly near the tip.

Lewis Research Center
National Aeronautics and Space Administration
Cleveland, Ohio, February 18, 1981

Appendix A

Symbols

CL normal clearance over a rotor, cm

C_p specific heat at constant pressure, J/kg-K

D_f diffusion factor

h enthalpy, J/kg

Δh specific work, J/kg

i index

MFR mass flow ratio

$\dot{m}$ mass flow rate, kg/sec

N rotative speed, rpm

NR number of radial positions

p pressure, N/cm^2

R radius, cm

R_G gas constant, J/kg-K

T temperature, K

u wheel speed, m/sec

V absolute velocity, m/sec

W relative velocity, m/sec

Z axial distance measured along rotor centerline, cm

α absolute flow angle measured from meridional direction, deg

β relative flow angle measured from meridional direction, deg

γ ratio of specific heats

δ ratio of inlet total pressure to standard sea level pressure, P'_0/P_{STD}, $P_{STD} = 101325.04\ NT/m^2$

η efficiency

θ ratio of rotor inlet total temperature to standard temperature, T'_0/T_{STD}, $T_{STD} = 288.15$ K, or cylindrical angle, deg

κ_{mc} angle between blade mean camber line and meridional direction, deg

σ solidity, ratio of chord to spacing

ρ density, kg/m^3

Φ entropy function, J/kg-K

ϕ angle between end walls and axial direction, deg

$\overline{\omega}$ total pressure loss coefficient

Subscripts:

AD adiabatic

AVG average

D design conditions

cr critical conditions

EQ equivalent conditions, refer to NASA Standard Conditions

H hub

ID ideal

LE blade leading edge

MC blade mean camber line

m meridional direction

T tip

TE blade trailing edge

θ tangential direction

0 inlet plenum

1 survey station in front of rotor 1

2 survey station between rotors 1 and 2

3 survey station behind rotor 2

7 overall measurement station

Superscripts:

$'$ absolute total conditions

$''$ relative total conditions

Appendix B

Equations Used in Data Reduction Programs

The following equations were used to calculate overall stages, rotor only, and blade element performance.

Overall Performance

Adiabatic efficiency:

$$\eta_{AD} = \frac{\Delta h'_{ID}}{\Delta h'_{\text{actual}}} = \frac{h'_{ID,7} - h'_0}{h'_{\text{actual},7} - h'_0}$$

Equivalent mass flow rate:

$$\dot{m}\sqrt{\theta}/\delta$$

Mass flow ratio:

$$MFR = (\dot{m}/\dot{m}_D)_{EQ}$$

Calculated total pressure for rotor:

$$(V_\theta)_{AVG} = (h'_7 - h'_0)/u_{AVG}$$

Assume $V_{m,AVG}$.

$$V_{AVG} = (V_\theta^2 + V_m^2)^{1/2}_{AVG}$$

$$h_{AVG} = h'_7 - V_{AVG}^2/2$$

$$T_{AVG} = \text{function } (h_{AVG})$$

$$p_{AVG} = (p_{hub} + p_{shroud})/2$$

$$\rho_{AVG} = \frac{p_{AVG}}{R_G T_{AVG}}$$

$$\dot{m} = 0.98\, \rho_{AVG} V_{m,AVG} \pi (R_T + R_H)(R_T - R_H) \times \cos\left(\frac{\Phi_T + \Phi_H}{2}\right)$$

$$p'_{AVG} = p'_0\, e^{\text{EXP}/R_G}$$

where

$$\text{EXP} = \Phi' - \Phi'_0 - \Phi + \Phi_0 + R_G \ln(p/p_0)$$

$$\Phi = \int_{T_{\text{reference}}}^{T} \frac{C_p}{T}\, dt$$

Blade Element Data

Adiabatic efficiency:

$$\eta_{AD} = \frac{[(p'_{TE}/p'_{LE})^{(\gamma-1)/\gamma}] - 1}{(T'_{TE}/T'_{LE}) - 1};\ \gamma = 1.4$$

Diffusion factor:

$$D_f = 1 - \frac{W_{TE}}{W_{LE}} + \frac{(RV_\theta)_{TE} - (RV_\theta)_{LE}}{(R_{TE} + R_{LE})\sigma W_{LE}}$$

Total pressure loss coefficient:

$$\overline{\omega} = \frac{(p''_{ID})_{TE} - p''_{TE}}{p''_{LE} - p_{LE}}$$

Critical velocity:

$$V_{cr} = \left(\frac{2\gamma}{\gamma+1} R_G T'\right)^{1/2}$$

Energy-averaged efficiency:

$$\eta = \frac{\left\{\dfrac{\sum_{i=1}^{NR}\left[(p'/p'_0)^{(\gamma-1)/\gamma}\right]\Delta\dot{m}_i}{\sum_{i=1}^{NR}\Delta\dot{m}_i} - 1\right\}}{\dfrac{\sum_{i=1}^{NR}\Delta\dot{m}_i T'_i}{T'_0\sum_{i=1}^{NR}\Delta\dot{m}_i} - 1}$$

Incidence angle:

$$\beta_{LE} - (\kappa_{mc})_{LE}$$

Deviation angle:

$$\beta_{TE} - (\kappa_{mc})_{TE}$$

References

1. Klassen, Hugh A.; Wood, Jerry R.; and Schumann, Lawrence F.: Experimental Performance of a 16.10-Centimeter-Tip-Diameter Sweptback Centifugal Compressor Designed for a 6:1 Pressure Ratio. NASA TM X-3552, 1977.

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3. Bryce, C. A.; et al.: Advanced Two-Stage Compressor Program Design of Inlet Stage. (AT-6133-R, AiResearch Mfg. Co.; NASA Contract NAS3-15324). NASA CR-120943, 1973.

4. Katsanis, Theodore; and McNally, William D.: Revised Fortran Program for Calculating Velocities and Streamlines on the Hub-Shroud Midchannel Stream Surface of an Axial-, Radial-, or Mixed-Flow Turbomachine or Annular Duct. I—User's Manual. NASA TN D-8430, 1977.

TABLE I.—ROTOR AND STAGE DESIGN PARAMETERS

Stage overall design performance:	
Total pressure ratio	3.06
Adiabatic efficiency	0.906
Total temperature ratio	1.4121
Critical velocity ratio at exit	0.31
Rotor 1 inlet tip speed, m/sec	355.7
Equivalent mass flow rate, kg/sec	0.9072
Flow rate/unit annulus area, kg/sec/m^2	153.7
Equivalent speed, rpm	69 900
Rotor 1 overall design performance:	
Total pressure ratio	1.78
Adiabatic efficiency	0.955
Total temperature ratio	1.186
Rotor 2 overall design performance:	
Total pressure ratio	1.821
Adiabatic efficiency	0.968
Total temperature ratio	1.191
Inlet equivalent mass flow rate, kg/sec	0.555
Combined rotor overall design performance:	
Total pressure ratio	3.241
Adiabatic efficiency	0.960

TABLE II.—BLADE ELEMENT DATA—DESIGN CONDITIONS

[Mass flow ratio, 1.0; design speed, 100 percent; plenum pressure, 101 325.04 N/m^2; plenum temperature, 288.15 K.]

(a) Rotor 1

ROTOR LEADING EDGE

RADIUS (CM)	% SPAN FROM HUB	STREAM LINE	TOTAL PRESSURE/ PLENUM TOTAL PRESSURE (P'/P'_0)	TOTAL TEMPERATURE/ PLENUM TOTAL TEMPERATURE (T'/T'_0)	RELATIVE CRITICAL VELOCITY RATIO (W/W_{cr})	ABSOLUTE CRITICAL VELOCITY RATIO (V/V_{cr})	ABSOLUTE FLOW ANGLE (α)	RELATIVE FLOW ANGLE (β)	INCIDENCE ANGLE
2.196	0.0	0.0	1.0000	1.0000	0.620	0.365	0.000	54.819	5.029
3.339	42.9	25.0			.883	.490		58.104	4.334
3.964	66.4	50.0			1.029	.581		58.123	3.553
4.445	84.5	75.0			1.123	.625		59.204	3.374
4.700	94.0	90.0			1.169	.645		59.800	2.870
4.859	100.0	100.0			1.200	.663		59.937	2.217

ROTOR TRAILING EDGE

RADIUS (CM)	% SPAN FROM HUB	STREAM LINE	TOTAL PRESSURE/ PLENUM TOTAL PRESSURE (P'/P'_0)	TOTAL TEMPERATURE/ PLENUM TOTAL TEMPERATURE (T'/T'_0)	EFFICIENCY REFERENCED TO PLENUM CONDITIONS	RELATIVE CRITICAL VELOCITY RATIO (W/W_{cr})	ABSOLUTE CRITICAL VELOCITY RATIO (V/V_{cr})	ABSOLUTE FLOW ANGLE (α)	RELATIVE FLOW ANGLE (β)	DEVIATION ANGLE
3.693	0.0	0.0	1.7407	1.1733	0.9799	0.518	0.714	51.530	28.877	14.117
4.274	33.8	25.0	1.7656	1.1774	.9841	.628	.665	47.701	44.311	9.061
4.716	59.6	50.0	1.7805	1.1824	.9724	.726	.652	44.516	50.554	5.664
5.079	80.7	75.0	1.7955	1.1899	.9487	.797	.650	42.669	53.961	4.851
5.282	92.5	90.0	1.8075	1.2069	.8816	.804	.653	44.593	55.436	5.286
5.410	100.0	100.0	1.8205	1.2124	.8698	.828	.661	43.944	55.784	5.244

ELEMENT DATA AT TRAILING EDGE

STREAM LINE	PRESSURE RATIO	TEMPERATURE RATIO	EFFICIENCY	DIFFUSION FACTOR	TOTAL PRESSURE LOSS COEFFICIENT
0.0	1.7407	1.1733	0.980	0.397	0.066
25.0	1.7656	1.1774	.984	.444	.027
50.0	1.7805	1.1824	.972	.434	.036
75.0	1.7955	1.1899	.949	.420	.060
90.0	1.8075	1.2069	.882	.448	.137
100.0	1.8205	1.2124	.870	.446	.147

TABLE II.—Concluded. BLADE ELEMENT DATA—DESIGN CONDITIONS

[Mass flow ratio, 1.0; design speed, 100 percent; plenum pressure, 101 325.04 N/m^2; plenum temperature, 288.15 K.]

(b) Rotor 2

ROTOR LEADING EDGE

RADIUS (CM)	% SPAN FROM HUB	STREAM LINE	TOTAL PRESSURE/ PLENUM TOTAL PRESSURE (P'/P'_0)	TOTAL TEMPERATURE/ PLENUM TOTAL TEMPERATURE (T'/T'_0)	RELATIVE CRITICAL VELOCITY RATIO (W/W_{cr})	ABSOLUTE CRITICAL VELOCITY RATIO (V/V_{cr})	ABSOLUTE FLOW ANGLE (α)	RELATIVE FLOW ANGLE (β)	INCIDENCE ANGLE
4.395	0.0	0.0	1.7470	1.1733	0.658	0.644	46.614	47.833	3.933
4.916	34.8	25.0	1.7626	1.1774	.810	.673	39.449	50.944	3.944
5.294	60.1	50.0	1.7787	1.1824	.904	.696	35.787	52.674	3.074
5.611	81.3	75.0	1.7862	1.1895	.962	.707	34.386	54.376	3.376
5.782	92.7	90.0	1.8127	1.2069	.970	.720	35.565	54.526	2.526
5.892	100.0	100.0	1.8254	1.2126	.984	.724	35.564	55.004	2.004

ROTOR TRAILING EDGE

RADIUS (CM)	% SPAN FROM HUB	STREAM LINE	TOTAL PRESSURE/ PLENUM TOTAL PRESSURE (P'/P'_0)	TOTAL TEMPERATURE/ PLENUM TOTAL TEMPERATURE (T'/T'_0)	EFFICIENCY REFERENCED TO PLENUM CONDITIONS	RELATIVE CRITICAL VELOCITY RATIO (W/W_{cr})	ABSOLUTE CRITICAL VELOCITY RATIO (V/V_{cr})	ABSOLUTE FLOW ANGLE (α)	RELATIVE FLOW ANGLE (β)	DEVIATION ANGLE
5.483	0.0	0.0	3.3296	1.4103	0.9884	0.632	0.970	56.666	27.591	11.791
5.733	25.8	25.0	3.2421	1.4006	.9859	.650	.907	56.868	37.718	7.018
5.968	50.0	50.0	3.1953	1.3985	.9768	.668	.858	57.838	45.415	5.415
6.197	73.6	75.0	3.2157	1.4127	.9492	.678	.837	59.421	50.095	3.495
6.346	89.0	90.0	3.2752	1.4476	.8915	.624	.835	64.617	53.845	5.145
6.453	100.0	100.0	3.2667	1.4514	.8815	.630	.817	65.965	57.189	7.289

ELEMENT DATA AT TRAILING EDGE

STREAM LINE	PRESSURE RATIO	TEMPERATURE RATIO	EFFICIENCY	DIFFUSION FACTOR	TOTAL PRESSURE LOSS COEFFICIENT
0.0	1.9059	1.2019	0.992	0.219	0.029
25.0	1.8394	1.1896	.993	.348	.015
50.0	1.7965	1.1828	.987	.394	.022
75.0	1.8003	1.1876	.965	.423	.052
90.0	1.8068	1.1994	.914	.497	.131
100.0	1.7895	1.1969	.909	.493	.133

TABLE III.—BLADE DESIGN PARAMETERS

	Rotor 1	Rotor 2
Tip diffusion factor, D_f	0.443	0.493
Tip relative velocity ratio, W_{TE}/W_{LE}	0.707	0.655
Inlet hub to tip radius ratio	0.45	0.746
Inlet tip relative Mach number	1.256	0.981
Mean blade height to mean chord ratio	1.028	0.84
Tip solidity, σ	1.34	1.57
Number of blades	20	40
Mean blade height, cm	2.195	1.256
	Stator 1	Stator 2
Hub inlet Mach number	0.848	0.423
Hub solidity, σ	1.891	1.63
Number of vanes	53	53
Mean blade height to mean chord ratio	0.604	0.494
Tip diffusion factor, D_f	0.57	0.49

TABLE IV—INSTRUMENTATION STATIONS

(a) Static pressure taps

Station	Shroud coordinates			Hub coordinates		
	Z, cm	R, cm	θ, deg	Z, cm	R, cm	θ, deg
1.0	0	4.597	0	----	----	----
1.02	.508	4.640	0	----	----	----
1.04	1.016	4.740	0	----	----	----
1.1	1.417	4.859	350	----	----	----
1.2	1.783	5.020	↓	----	----	----
1.3	2.148	5.210	↓	----	----	----
1.4	2.509	5.420	↓	----	----	----
2.0	2.855	5.662	230	----	----	----
2.0	2.855	5.662	325	----	----	----
2.0	2.855	5.662	45	----	----	----
2.1	3.195	5.920	↓	----	----	----
2.2	3.393	6.050	↓	----	----	----
2.3	3.632	6.240	↓	----	----	----
2.4	3.906	6.470	↓	----	----	----
3.0	4.272	6.789	241.2	4.272	5.784	209.7
↓	↓	↓	239.2	↓	↓	211.7
↓	↓	↓	237.2	↓	↓	213.7
↓	↓	↓	235.2	↓	↓	217.7
[a]3.1	4.719	7.186	353.8	4.719	6.281	353.8
3.2	4.975	7.409	344.4	4.996	6.561	344.4
3.3	5.227	7.620	348.1	5.273	6.779	348.1
3.4	5.456	7.815	339.6	5.532	7.059	339.6
4.0	5.847	8.098	220.8	5.903	7.358	220.8
↓	↓	↓	219.1	↓	↓	219.1
↓	↓	↓	217.4	↓	↓	217.4
↓	↓	↓	215.7	↓	↓	215.7
↓	↓	↓	314.0	↓	↓	214.0
4.1	6.096	8.263	32.6	6.096	7.506	32.6
4.2	6.520	8.542	30.7	6.515	7.813	30.7
4.3	6.944	8.771	29.9	6.939	8.047	29.9
4.4	7.368	8.961	29.8	7.335	8.255	29.8
5.0	8.182	9.301	236.9	8.453	8.705	236.9
↓	↓	↓	235.2	↓	↓	235.2
↓	↓	↓	233.5	↓	↓	233.5
↓	↓	↓	231.8	↓	↓	231.8
↓	↓	↓	230.1	↓	↓	230.1
7.0	9.271	11.71	145	----	----	----
↓	↓	↓	150	----	----	----
↓	↓	↓	155	----	----	----
↓	↓	↓	160	----	----	----

[a]Last static station for rotor only test.

(b) Fixed instrumentation

Station	Type	Quantity	Location		
			Z, cm	R, cm	θ, deg
0	Total pressure	8	See plenum–figure 5		
0	Total temperature	4	See plenum–figure 5		
7	Total pressure	4	9.592	11.71	0, 90, 180, 270
7	Total temperature	4	9.592	11.71	15, 105, 195, 258

(c) Survey instrumentation—rotor only test

Station	Type	Quantity	θ, deg
1.0	Total pressure	1	240
1.0	Total temperature	↓	240
1.0	Angle	↓	240
2.0	Total pressure	↓	150
2.0	Total temperature	↓	150
2.0	Angle	↓	150
3.0	Total pressure	↓	210
3.0	Total temperature	↓	210
3.0	Angle	↓	210

TABLE V.—OVERALL STAGE PERFORMANCE

Percent design equivalent speed, $(N/N_D \times 100)_{EQ}$	Mass flow ratio, $(\dot{m}/\dot{m}_D)_{EQ}$	Pressure ratio, p_7'/p_0'	Efficiency, η_{0-7}	Temperature ratio, T_7'/T_0'
Small clearance				
90	0.865	1.743	0.550	1.3118
	.831	2.179	.772	1.3220
	.809	2.220	.777	1.3284
	.779	2.247	.773	1.3357
95	.932	1.888	.565	1.3516
	.902	2.374	.775	1.3609
	.892	2.403	.779	1.3647
	.871	2.430	.778	1.3702
100	.995	2.048	.578	1.3924
	.971	2.577	.770	1.4020
	.958	2.613	.774	1.4070
	.934	2.66	.771	1.4172
Medium clearance				
50	0.507	0.916	−0.33	1.074
	.415	1.261	.724	1.095
	.398	1.280	.745	1.098
	.359	1.300	.755	1.103
	.313	1.295	.717	1.107
	.256	1.288	.680	1.110
70	.653	1.387	.548	1.179
	.594	1.615	.754	1.195
	.572	1.642	.763	1.120
	.554	1.650	.762	1.202
	.528	1.646	.752	1.203
	.422	1.599	.685	1.209
80	.753	1.572	.571	1.241
	.736	1.783	.725	1.248
	.709	1.848	.756	1.254
	.651	1.911	.761	1.267
	.589	1.842	.715	1.266
	.569	1.828	.705	1.267
90	0.870	1.759	0.562	1.311
	.837	2.160	.765	1.321
	.815	2.206	.772	1.328
	.799	2.226	.771	1.333
	.764	2.240	.763	1.339
	.747	2.236	.754	1.3419
95	.902	2.360	.767	1.3615
	.895	2.377	.770	1.3635
	.885	2.399	.772	1.3668
	.871	2.412	.772	1.3696
100	.999	1.986	.549	1.3931
	.983	2.485	.746	1.3971
	.975	2.528	.756	1.3999
	.951	2.588	.767	1.4059
	.915	2.620	.759	1.4162
	.884	2.619	.752	1.4199
Large clearance				
90	0.864	1.685	0.513	1.3122
	.827	2.125	.745	1.3208
	.816	2.138	.748	1.3224
	.785	2.184	.752	1.3309
	.749	2.194	.744	1.3368
95	.900	2.266	.740	1.3550
	.873	2.345	.756	1.3637
	.852	2.372	.756	1.3691
	.832	2.382	.754	1.3723
100	.981	2.050	.578	1.3928
	.970	2.439	.731	1.3954
	.954	2.511	.748	1.4009
	.947	2.518	.750	1.4014
	.925	2.545	.752	1.4053
	.862	2.553	.738	1.4147

TABLE VI.—STATIC PRESSURE RATIO DISTRIBUTION AT 100 PERCENT SPEED FOR STAGE TEST AT SMALL CLEARANCE FOR PEAK STAGE EFFICIENCY AND PEAK STAGE PRESSURE RATIO

Station	Station pressure ratio, p/p_0'			
	Peak stage efficiency ($MFR = 0.958$)		Peak stage pressure ratio ($MFR = 0.934$)	
	Shroud	Hub	Shroud	Hub
1.0	0.869	----	0.878	----
1.02	.834	----	.844	----
1.04	.811	----	.824	----
1.1	.799	----	.816	----
1.2	.896	----	.954	----
1.3	1.102	----	1.154	----
1.4	1.312	----	1.342	----
2.0	1.333	----	1.369	----
2.0	1.358	----	1.393	----
2.0	1.335	----	1.371	----
2.1	1.356	----	1.395	----
2.2	1.462	----	1.507	----
2.3	1.632	----	1.680	----
2.4	1.890	----	1.936	----
3.0	1.928	1.683	1.957	1.712
↓	1.926	1.620	1.961	1.650
	1.916	1.659	1.953	1.685
	1.956	1.707	1.992	1.734
3.1	1.846	1.849	1.943	1.894
3.2	2.133	1.936	2.191	2.041
3.3	2.189	2.125	2.242	2.191
3.4	2.278	2.170	2.346	2.226
4.0	2.233	2.154	2.313	2.236
↓	2.237	2.151	2.310	2.236
	2.227	2.133	2.308	2.217
	----	2.123	----	2.203
	2.230	2.134	2.310	2.217
4.1	2.352	2.285	2.419	2.356
4.2	2.430	2.384	2.495	2.453
4.3	2.482	2.423	2.542	2.487
4.4	2.466	2.452	2.528	2.512
5.0	2.461	2.438	2.518	2.497
↓	2.458	2.443	2.517	2.502
	2.457	2.445	2.519	2.505
	2.452	2.443	2.507	2.505
	2.455	2.441	2.514	2.503
7.0	2.477	----	2.533	----
↓	2.475	----	2.535	----
	2.478	----	2.556	----
	2.473	----	2.533	----

TABLE VII.—STATIC PRESSURE RATIO AT VARIOUS STATIONS FOR MEDIUM CLEARANCE STAGE TEST

Percent design equivalent speed, $(N/N_D \times 100)_{EQ}$	Mass flow ratio, MFR	Static pressure ratio, p/p_0'											
		Station											
		1.1	1.2	1.3	1.4	2.0	2.1	2.2	2.3	2.4	3.0	4.0	5.0
70	0.653	0.914	0.981	1.030	1.122	1.126	1.124	1.138	1.191	1.275	1.312	1.088	1.273
	.594	.940	1.002	1.077	1.159	1.163	1.166	1.195	1.261	1.346	1.363	1.435	1.534
	.572	.949	1.007	1.093	1.169	1.174	1.179	1.212	1.278	1.360	1.382	1.480	1.567
	.554	.955	1.008	1.098	1.173	1.175	1.183	1.218	1.284	1.364	1.390	1.500	1.580
	.528	.963	1.008	1.083	1.161	1.164	1.174	1.214	1.286	1.369	1.388	1.508	1.582
	.422	.989	1.027	1.100	1.174	1.181	1.190	1.219	1.286	1.369	1.397	1.492	1.549
80	.753	.887	.976	1.040	1.170	1.178	1.175	1.204	1.279	1.409	1.476	1.183	1.431
	.736	.897	1.001	1.060	1.188	1.196	1.197	1.232	1.317	1.447	1.488	1.485	1.666
	.709	.908	1.022	1.080	1.204	1.212	1.216	1.256	1.349	1.475	1.507	1.600	1.744
	.651	.941	1.009	1.116	1.228	1.237	1.251	1.296	1.390	1.514	1.546	1.717	1.825
	.589	.950	1.017	1.098	1.212	1.224	1.234	1.275	1.365	1.490	1.525	1.675	1.776
	.569	.956	1.020	1.104	1.217	1.226	1.236	1.276	1.369	1.493	1.525	1.670	1.758
90	.870	.838	.943	1.061	1.214	1.237	1.240	1.286	1.387	1.577	1.672	1.267	1.576
	.837	.862	.995	1.099	1.253	1.274	1.280	1.337	1.451	1.648	1.692	1.831	2.028
	.815	.876	1.018	1.119	1.273	1.291	1.301	1.362	1.483	1.673	1.713	1.910	2.082
	.797	.886	1.034	1.129	1.282	1.302	1.312	1.377	1.501	1.692	1.726	1.949	2.108
	.764	.904	1.054	1.165	1.299	1.324	1.334	1.399	1.520	1.709	1.746	1.995	2.136
	.747	.913	1.047	1.176	1.305	1.327	1.341	1.405	1.525	1.708	1.760	2.000	2.133
100	.999	.776	.825	1.035	1.230	1.274	1.282	1.360	1.511	1.761	1.880	1.397	1.757
	.983	.787	.849	1.063	1.264	1.305	1.314	1.396	1.550	1.813	1.897	2.050	2.319
	.975	.793	.868	1.079	1.280	1.319	1.331	1.416	1.569	1.835	1.903	2.113	2.365
	.951	.811	.924	1.119	1.310	1.351	1.367	1.454	1.616	1.885	1.934	2.214	2.438
	.915	.834	.973	1.171	1.351	1.384	1.403	1.494	1.651	1.915	1.962	2.286	2.481
	.884	.853	1.002	1.206	1.374	1.401	1.426	1.510	1.669	1.913	1.974	2.315	2.495

TABLE VIII.—ROTOR PERFORMANCE FOR ROTOR ONLY TEST

(a) Performance based on calculated total pressure at station 3 referenced to plenum conditions

Percent design equivalent speed, $(N/N_D \times 100)_{EQ}$	Mass flow ratio, $(\dot{m}/\dot{m}_D)_{EQ}$	Pressure ratio, p_3'/p_0'	Efficiency, η_{0-3}	Temperature ratio, T_3'/T_0'
80	0.810	1.881	0.885	1.2231
	.743	1.989	.883	1.2452
	.662	2.064	.864	1.2654
	.594	1.987	.821	1.2632
	.461	1.985	.771	1.2800
	.404	1.996	.753	1.2890
90	.919	2.244	.877	1.2948
	.908	2.279	.881	1.2998
	.888	2.338	.886	1.3085
	.824	2.423	.876	1.3266
	.752	2.480	.855	1.3444
95	.977	2.356	.853	1.3241
	.963	2.451	.868	1.3351
	.933	2.581	.881	1.3518
	.887	2.657	.876	1.3659
	.814	2.707	.856	1.3825
100	1.018	2.639	.850	1.3741
	.999	2.805	.868	1.3930
	.977	2.861	.872	1.3997
	.952	2.948	.878	1.4104
	.926	2.955	.867	1.4163
	.883	2.974	.863	1.4214

(b) Performance based on survey results referred to plenum conditions

Percent design equivalent speed, $(N/N_D \times 100)_{EQ}$	Mass flow ratio, $(\dot{m}/\dot{m}_D)_{EQ}$	Station 1		Station 2			Station 3		
		Pressure ratio, p_1'/p_0'	Temperature ratio, T_1'/T_0'	Pressure ratio, p_2'/p_0'	Temperature ratio T_2'/T_0'	Efficiency, η_{0-2}	Pressure ratio, p_3'/p_0'	Temperature ratio, T_3'/T_0'	Efficiency, η_{0-3}
100	1.00	0.9930	1.0027	1.6734	1.1845	0.859	2.8154	1.3969	0.867
100	.95	.9934	1.0030	1.7569	1.2021	.864	2.9515	1.4161	.871
100	.88	.9930	1.0037	1.7845	1.2158	.834	2.9823	1.4321	.848
80	.77	.9971	1.0017	1.4261	1.1208	.883	1.9850	1.2396	.903

(c) Performance based on survey results across the rotors

Percent design equivalent speed, $(N/N_D \times 100)_{EQ}$	Mass flow ratio, $(\dot{m}/\dot{m}_D)_{EQ}$	Rotor 1				Rotor 2				Both rotors		
		Inlet equivalent flow to design mass flow	Pressure ratio, p_2'/p_1'	Temperature ratio, T_2'/T_1'	Efficiency, η_{1-2}	Inlet equivalent flow to design mass flow	Pressure ratio p_3'/p_2'	Temperature ratio, T_3'/T_2'	Efficiency, η_{2-3}	Pressure ratio, p_3'/p_1'	Temperature ratio, T_3'/T_1'	Efficiency, η_{1-3}
100	1.00	1.008	1.6852	1.1813	0.887	0.650	1.6824	1.1792	0.894	2.8352	1.3930	0.882
100	.95	.958	1.7686	1.1985	.891	.593	1.6799	1.1780	.897	2.9711	1.4119	.886
100	.88	.888	1.7971	1.2113	.863	.544	1.6712	1.1779	.888	3.0033	1.4268	.865
80	.77	.773	1.4302	1.1189	.905	.572	1.3879	1.1079	.910	1.9908	1.2375	.915

TABLE IX.—STATIC PRESSURE RATIO DISTRIBUTION ALONG SHROUD FOR ROTOR ONLY TEST AT 100-PERCENT SPEED

Station	Static pressure ratio		
	Mass flow ratio, *MFR*		
	1.000	0.950	0.880
1.0	0.864	0.875	0.898
1.02	.823	.849	.873
1.04	.797	.828	.860
1.1	.770	.815	.851
1.2	.811	.954	1.034
1.3	1.054	1.148	1.211
1.4	1.224	1.336	1.350
2.0	1.246	1.347	1.400
2.0	1.258	1.371	1.397
2.0	1.276	1.365	1.411
2.1	1.279	1.387	1.436
2.2	1.375	1.495	1.546
2.3	1.539	1.655	1.710
2.4	1.810	1.916	1.947
3.0	1.937	2.043	2.077
3.0	1.925	2.040	2.076
3.0	1.926	2.033	2.066
3.1	1.931	2.047	2.083
3.1	1.959	2.079	2.116
3.1	1.989	2.107	2.142

TABLE X.—STATION 1 SURVEY DATA

[Pressures referenced to plenum pressure, 101 325.04 N/m²; temperature referenced to plenum temperature, 288.15 K.]

(a) Mass flow ratio, 1.0; speed, 100 percent design

Radius, cm	Total pressure ratio	Total temperature ratio	Static pressure ratio[a]	Absolute flow angle, deg	Percent span from hub	Mach number
1.285	------	-----	------	-	0	------
1.415	1.000	1.003	0.8790	0	3.917	0.4332
1.468		1.002	.8820		5.530	.4274
1.567			.8860		8.525	.4194
1.722			.8930		13.21	.4054
1.925	.9990		.8980		19.35	.3932
2.126		1.001	.8990		25.42	.3911
2.332		1.001	.8990		31.64	.3911
2.484		1.001	.8990		36.25	.3911
2.677		1.002	.8980		42.09	.3932
2.896		1.001	.8960		48.69	.3974
3.086	.9970		.8930		54.45	.3999
3.287	.9970		.8900		60.52	.4060
3.485	.9950		.8850		66.51	.4125
3.698	.9950		.8820		72.96	.4186
3.901	.9930		.8770		79.11	.4250
4.045	.9920		.8730		83.72	.4312
4.156	.9900	1.002	.8710		86.79	.4317
4.258	.9860	1.002	.8690		89.86	.4287
4.361	.9840	1.003	.8680		93.01	.4271
4.412	.9810	1.004	.8670		94.55	.4238
4.465	.9750	1.006	.8660		96.16	.4150
4.516	.9690	1.013	.8650		97.70	.4060
4.565	.9520	1.030	.8640		99.17	.3748
4.597	------	-----	.8640	-	100.00	------

(b) Mass flow ratio, 0.95; speed, 100 percent design

Radius, cm	Total pressure ratio	Total temperature ratio	Static pressure ratio[a]	Absolute flow angle, deg	Percent span from hub	Mach number
1.285	------	-----	------	-	0	------
1.415	1.001	1.002	0.9875	0	3.917	0.4182
1.468	1.001	1.002	.8900		5.530	.4132
1.567	1.000	1.001	.8955		8.525	.4002
1.722		1.001	.9015		13.21	.3878
1.925		1.001	.9064		19.35	.3773
2.126		1.000	.9087		25.42	.3724
2.332	.9990		.9090		31.64	.3697
2.484			.9090		36.25	.3697
2.677			.9080		42.09	.3719
2.896			.9068		48.69	.3745
3.086	.9980		.9042		54.45	.3782
3.287	.9970	1.001	.9014		60.52	.3822
3.485	.9960	1.000	.8982		66.51	.3871
3.698	.9950	1.001	.8941		72.96	.3938
3.901	.9920	1.000	.8895		79.11	.3978
4.045	.9910	1.001	.8869		83.72	.4014
4.156	.9900	1.001	.8850		86.79	.4034
4.258	.9870	1.002	.8835		89.86	.4010
4.361	.9830	1.002	.8815		93.01	.3977
4.412	.9810	1.005	.8805		94.55	.3960
4.465	.9770	1.007	.8795		96.16	.3905
4.516	.9710	1.033	.8770		97.70	.3842
4.565	.9580	1.061	.8760		99.17	.3598
4.597	------	-----	.8750	-	100.00	------

[a]Static pressure ratio obtained as explained in Calculation Procedures section.

TABLE X.—Concluded. STATION 1 SURVEY DATA

[Pressures referenced to plenum pressure, 101 325.04 N/m^2; temperature referenced to plenum temperature, 288.15 K.]

(c) Mass flow ratio, 0.88; speed, 100 percent design

Radius, cm	Total pressure ratio	Total temperature ratio	Static pressure ratio[a]	Absolute flow angle, deg	Percent span from hub	Mach number
1.285	------	-----	------	-	0	------
1.415	0.9990	1.003	0.9045	0	3.917	0.3795
1.468			.9072		5.530	.3737
1.567			.9105		8.525	.3665
1.722			.9152		13.21	.3560
1.925		1.002	.9190		19.35	.3474
2.126			.9210		25.42	.3428
2.332	.9980		.9219		31.64	.3385
2.484			.9215		36.25	.3395
2.677			.9208		42.09	.3411
2.896			.9190		48.69	.3453
3.086	.9970		.9172		54.45	.3473
3.287	.9960		.9150		60.52	.3502
3.485	.9950		.9123		66.51	.3543
3.698	.9940		.9090		72.96	.3596
3.901	.9920		.9059		79.11	.3625
4.045	.9910		.9025		83.72	.3680
4.156	.9900	1.003	.9009		86.79	.3695
4.258	.9870	1.003	.8999		89.86	.3657
4.361	.9850	1.004	.8989		93.01	.3639
4.412	.9820	1.005	.8982		94.55	.3593
4.465	.9780	1.009	.8980		96.16	.3513
4.516	.9730	1.017	.8978		97.70	.3409
4.565	.9610	1.039	.8975		99.17	.3140
4.597	------	-----	.8980	-	100.00	------

(d) Mass flow ratio, 0.77; speed, 80 percent design

Radius, cm	Total pressure ratio	Total temperature ratio	Static pressure ratio[a]	Absolute flow angle, deg	Percent span from hub	Mach number
1.285	------	-----	------	-	0	------
1.415	1.001	1.002	0.9320	0	3.917	0.3211
1.468		1.002	.9337		5.530	.3169
1.567		1.001	.9364		8.525	.3102
1.722			.9400		13.21	.3011
1.925			.9435		19.35	.2919
2.126			.9458		25.42	.2858
2.332			.9460		31.64	.2853
2.484			.9450		36.25	.2880
2.677	1.000		.9442		42.09	.2876
2.896	1.000		.9432		48.69	.2902
3.086	1.000		.9421		54.45	.2931
3.287	.9990		.9391		60.52	.2985
3.485	.9990	1.000	.9375		66.51	.3027
3.698	.9980	1.000	.9351		72.96	.3064
3.901	.9980	1.001	.9320		79.11	.3142
4.045	.9960	1.001	.9300		83.72	.3145
4.156	.9950	1.001	.9284		86.79	.3162
4.258	.9930	1.002	.9270		89.86	.3150
4.361	.9910	1.002	.9262		93.01	.3123
4.412	.9900	1.003	.9252		94.55	.3125
4.465	.9860	1.005	.9245		96.16	.3047
4.516	.9840	1.009	.9240		97.70	.3011
4.565	.9750	1.020	.9238		99.17	.2787
4.597	------	-----	.9238	-	100.00	------

[a]Static pressure ratio obtained as explained in Calculation Procedures section.

TABLE XI.—STATION 2 SURVEY DATA

[Pressures referenced to plenum pressure, 101 325.04 N/m^2; temperature referenced to plenum temperature, 288.15 K.]

(a) Mass flow ratio, 1.0; speed, 100 percent design

Radius, cm	Total pressure ratio	Total temperature ratio	Static pressure ratio[a]	Absolute flow angle, deg	Percent span from hub	Mach number
3.909	-----	-----	-----	-----	0	------
4.040	1.767	1.187	1.237	52.31	7.461	0.7325
4.091	1.790	1.187	1.240	50.20	10.37	.7436
4.141	1.786	1.186	1.245	50.02	13.27	.7367
4.189	1.767	1.182	1.248	49.14	16.02	.7229
4.291	1.714	1.173	1.253	46.49	21.81	.6842
4.393	1.670	1.166	1.255	43.66	27.62	.6518
4.546	1.646	1.163	1.257	39.70	36.31	.6324
4.698	1.674	1.168	1.256	40.76	45.01	.6541
4.850	1.646	1.166	1.254	37.49	53.70	.6356
4.998	1.656	1.168	1.252	35.73	62.10	.6452
5.150	1.655	1.171	1.251	33.52	70.80	.6451
5.303	1.664	1.187	1.251	32.69	79.50	.6515
5.404	1.661	1.221	1.253	40.49	85.29	.6476
5.510	1.656	1.243	1.256	50.46	91.37	.6414
5.612	1.610	1.242	1.259	58.23	97.22	.6030
5.662	-----	-----	1.260	-----	100.00	------

(b) Mass flow ratio, 0.95; speed, 100 percent design

Radius, cm	Total pressure ratio	Total temperature ratio	Static pressure ratio[a]	Absolute flow angle, deg	Percent span from hub	Mach number
3.909	-----	-----	-----	-----	0	------
4.040	1.825	1.199	1.292	53.12	7.461	0.7200
4.091	1.850	1.197	1.298	52.72	10.37	.7296
4.141	1.851	1.195	1.302	52.62	13.27	.7273
4.189	1.838	1.194	1.306	51.72	16.02	.7159
4.291	1.798	1.186	1.312	49.62	21.81	.6866
4.393	1.754	1.179	1.316	47.46	27.62	.6537
4.546	1.704	1.176	1.322	44.46	36.31	.6131
4.698	1.733	1.183	1.325	44.64	45.01	.6314
4.850	1.737	1.185	1.326	44.99	53.70	.6335
4.998	1.739	1.186	1.328	43.14	62.10	.6330
5.150	1.742	1.191	1.331	39.87	70.80	.6320
5.303	1.754	1.220	1.334	40.31	79.50	.6378
5.404	1.770	1.244	1.338	48.17	85.29	.6451
5.510	1.778	1.255	1.342	54.62	91.37	.6472
5.612	1.704	1.255	1.348	59.11	97.22	.5882
5.662	-----	-----	1.361	-----	100.00	------

[a]Static pressure ratio and flow angle obtained as explained in Calculation Procedure section.

TABLE XI.—Concluded. STATION 2 SURVEY DATA

[Pressures referenced to plenum pressure, 101 325.04 N/m^2; temperature referenced to plenum temperature, 288.15 K.]

(c) Mass flow ratio, 0.88; speed, 100 percent design

Radius, cm	Total pressure ratio	Total temperature ratio	Static pressure ratio[a]	Absolute flow angle, deg	Percent span from hub	Mach number
3.909	-----	-----	-----	-----	0	------
4.040	1.857	1.204	1.297	56.81	7.461	0.7347
4.091	1.882	1.203	1.303	54.43	10.37	.7442
4.141	1.882	1.201	1.308	54.34	13.27	.7399
4.189	1.867	1.198	1.313	53.81	16.02	.7275
4.291	1.828	1.193	1.321	51.34	21.81	.6972
4.393	1.793	1.188	1.328	49.49	27.62	.6691
4.546	1.755	1.186	1.335	47.37	36.31	.6377
4.698	1.761	1.190	1.341	48.17	45.01	.6362
4.850	1.755	1.191	1.346	49.31	53.70	.6273
4.998	1.756	1.196	1.351	47.55	63.10	.6238
5.150	1.761	1.211	1.358	46.23	70.80	.6209
5.303	1.768	1.253	1.367	49.40	79.50	.6173
5.404	1.782	1.269	1.376	53.64	85.29	.6195
5.510	1.780	1.279	1.384	58.05	91.37	.6103
5.612	1.788	1.288	1.394	62.64	97.22	.6074
5.662	-----	-----	1.403	-----	100.00	------

(d) Mass flow ratio, 0.77; speed, 80 percent design

Radius, cm	Total pressure ratio	Total temperature ratio	Static pressure ratio[a]	Absolute flow angle, deg	Percent span from hub	Mach number
3.909	-----	-----	-----	-----	0	------
4.040	1.489	1.123	1.150	54.60	7.461	0.6189
4.091	1.493	1.124	1.160	52.80	10.37	.6112
4.141	1.487	1.122	1.162	51.60	13.27	.6043
4.189	1.479	1.120	1.164	50.50	16.02	.5950
4.291	1.456	1.117	1.166	48.20	21.81	.5725
4.393	1.435	1.112	1.168	46.00	27.62	.5500
4.546	1.415	1.111	1.171	43.20	36.31	.5267
4.698	1.423	1.113	1.171	42.70	45.01	.5351
4.850	1.419	1.113	1.170	41.0[illegible]	53.70	.5323
4.998	1.420	1.114	1.168	39.[illegible]	62.10	.5358
5.150	1.419	1.118	1.166	37.60	70.80	.5371
5.303	1.416	1.122	1.165	35.70	79.50	.5358
5.404	1.416	1.134	1.165	39.20	85.29	.5351
5.510	1.414	1.141	1.164	44.90	91.37	.5346
5.612	1.358	1.137	1.154	53.30	97.22	.4742
5.662	-----	-----	1.164	-----	100.00	------

[a]Static pressure ratio and flow angle obtained as explained in Calculation Procedure section.

TABLE XII.—STATION 3 SURVEY DATA

[Pressures referenced to plenum pressure, 101 325.04 N/m^2; temperature referenced to plenum temperature, 288.15 K.]

(a) Mass flow ratio, 1.0; speed, 100 percent design

Radius, cm	Total pressure ratio	Total temperature ratio	Static pressure ratio[a]	Absolute flow angle, deg	Percent span from hub	Mach number
5.750	-----	-----	1.720	-----	0	------
5.796	3.020	1.406	1.730	60.82	4.400	0.9289
5.814	3.012	1.407	1.734	55.35	6.112	.9245
5.862	3.094	1.399	1.743	54.82	10.76	.9437
5.913	3.089	1.390	1.753	54.55	15.65	.9371
5.964	3.012	1.378	1.764	54.55	20.54	.9091
6.068	2.805	1.355	1.784	51.90	30.56	.8305
6.170	2.720	1.352	1.805	49.69	40.34	.7885
6.271	2.691	1.362	1.825	49.78	50.12	.7667
6.373	2.673	1.384	1.846	51.10	59.90	.7471
6.477	2.706	1.420	1.866	53.22	69.93	.7484
6.579	2.786	1.454	1.887	56.94	79.71	.7676
6.680	2.825	1.463	1.907	60.65	89.49	.7706
6.777	2.675	1.456	1.926	75.95	98.78	.7011
6.789	-----	-----	1.919	-----	100.00	------

(b) Mass flow ratio, 0.95; speed, 100 percent design

Radius, cm	Total pressure ratio	Total temperature ratio	Static pressure ratio[a]	Absolute flow angle, deg	Percent span from hub	Mach number
5.750	-----	-----	1.805	-----	0	------
5.796	3.181	1.414	1.817	59.84	4.400	0.9315
5.814	3.167	1.414	1.821	58.41	6.112	.9257
5.862	3.221	1.409	1.832	57.97	10.76	.9354
5.914	3.195	1.400	1.843	57.70	15.65	.9225
5.964	3.103	1.389	1.855	57.70	20.54	.8901
6.068	2.889	1.370	1.878	55.67	30.56	.8092
6.169	2.813	1.375	1.901	53.78	40.34	.7696
6.271	2.810	1.388	1.924	53.81	50.12	.7563
6.373	2.828	1.410	1.947	55.05	59.90	.7502
6.476	2.879	1.443	1.970	57.44	69.93	.7568
6.578	2.952	1.473	1.993	60.62	79.71	.7707
6.680	2.988	1.488	2.016	63.50	89.49	.7716
6.776	2.913	1.481	2.037	79.14	98.78	.7331
6.789	-----	-----	2.039	-----	100.00	------

[a]Static pressure ratio and flow angle obtained as explained in Calculation Procedure section.

TABLE XII.—Concluded. STATION 3 SURVEY DATA

[Pressures referenced to plenum pressure, 101 325.04 N/m^2; temperature referenced to plenum temperature, 288.15 K.]

(c) Mass flow ratio, 0.88; speed, 100 percent design

Radius, cm	Total pressure ratio	Total temperature ratio	Static pressure ratio[a]	Absolute flow angle, deg	Percent span from hub	Mach number
5.750	-----	-----	1.821	-----	0	------
5.796	3.202	1.415	1.832	59.91	4.400	0.9300
5.814	3.184	1.415	1.836	59.91	6.112	.9230
5.862	3.234	1.410	1.848	59.38	10.76	.9313
5.914	3.196	1.401	1.860	59.03	15.65	.9145
5.964	3.103	1.391	1.872	58.89	20.54	.8810
6.068	2.908	1.382	1.898	57.79	30.56	.8054
6.169	2.825	1.389	1.922	57.35	40.34	.7625
6.271	2.821	1.406	1.947	57.61	50.12	.7474
6.373	2.854	1.431	1.972	58.23	59.90	.7465
6.476	2.915	1.466	1.997	60.26	69.93	.7554
6.578	2.995	1.501	2.022	63.62	79.71	.7706
6.680	3.084	1.527	2.046	66.66	89.49	.7886
6.776	2.992	1.515	2.070	80.86	98.78	.7449
6.789	-----	-----	2.073	-----	100.00	------

(d) Mass flow ratio, 0.77; speed, 80 percent design

Radius, cm	Total pressure ratio	Total temperature ratio	Static pressure ratio[a]	Absolute flow angle, deg	Percent span from hub	Mach number
5.750	-----	-----	1.381	-----	0	------
5.796	2.069	1.252	1.386	60.25	4.400	0.7789
5.814	2.071	1.251	1.388	53.50	6.112	.7783
5.862	2.129	1.249	1.393	52.70	10.76	.8028
5.913	2.138	1.245	1.398	52.00	15.65	.8031
5.964	2.105	1.238	1.404	51.80	20.54	.7834
6.068	2.002	1.222	1.415	49.50	30.56	.7216
6.170	1.947	1.219	1.426	47.40	40.34	.6817
6.271	1.935	1.220	1.437	46.80	50.12	.6656
6.373	1.933	1.229	1.449	47.20	59.90	.6554
6.477	1.942	1.245	1.460	48.90	69.93	.6517
6.579	1.961	1.265	1.471	52.10	79.71	.6543
6.680	1.962	1.267	1.482	55.30	89.49	.6462
6.777	1.855	1.255	1.493	69.10	98.78	.5660
6.789	-----	-----	1.494	-----	100.00	------

[a]Static pressure ratio and flow angle obtained as explained in Calculation Procedure section.

TABLE XIII.—ROTOR 1 BLADE ELEMENT DATA

[Plenum pressure, 101 325.04 N/m^2; plenum temperature, 288.15 K.]

(a) Mass flow ratio, 1.0; speed, 100 percent design

ROTOR LEADING EDGE

RADIUS (CM)	% SPAN FROM HUB	STREAM LINE	TOTAL PRESSURE/ PLENUM TOTAL PRESSURE (P'/P'_0)	TOTAL TEMPERATURE/ PLENUM TOTAL TEMPERATURE (T'/T'_0)	RELATIVE CRITICAL VELOCITY RATIO (W/W_{cr})	ABSOLUTE CRITICAL VELOCITY RATIO (V/V_{cr})	ABSOLUTE FLOW ANGLE (α)	RELATIVE FLOW ANGLE (β)	INCIDENCE ANGLE
2.747	20.7	0.1	0.9990	1.0010	0.722	0.373	0.000	60.063	8.063
3.144	35.6	.2	.9990		.812	.414		60.794	7.794
3.460	47.5	.3	.9990		.887	.457		60.724	7.024
3.725	57.4	.4	.9971		.946	.490		60.838	6.838
3.955	66.1	.5	.9952		.996	.517		60.971	6.671
4.162	73.9	.6	.9952		1.046	.555		60.464	5.464
4.351	80.9	.7	.9928		1.083	.573		60.801	5.101
4.527	87.5	.8	.9895	1.0019	1.120	.598		60.718	4.418
4.691	93.7	.9	.9838	1.0031	1.152	.614		60.909	3.909

ROTOR TRAILING EDGE

RADIUS (CM)	% SPAN FROM HUB	STREAM LINE	TOTAL PRESSURE/ PLENUM TOTAL PRESSURE (P'/P'_0)	TOTAL TEMPERATURE/ PLENUM TOTAL TEMPERATURE (T'/T'_0)	EFFICIENCY REFERENCED TO PLENUM CONDITIONS	RELATIVE CRITICAL VELOCITY RATIO (W/W_{cr})	ABSOLUTE CRITICAL VELOCITY RATIO (V/V_{cr})	ABSOLUTE FLOW ANGLE (α)	RELATIVE FLOW ANGLE (β)	DEVIATION ANGLE
3.940	14.3	0.1	1.7850	1.1859	0.9685	0.620	0.826	47.899	23.401	0.901
4.148	26.4	.2	1.6810	1.1672	.9568	.685	.746	42.594	36.041	6.241
4.335	37.2	.3	1.6470	1.1625	.9429	.746	.715	38.758	41.833	6.533
4.506	47.1	.4	1.6710	1.1679	.9410	.758	.732	39.908	42.383	2.383
4.666	56.4	.5	1.6500	1.1665	.9239	.818	.715	36.132	45.930	2.630
4.814	65.0	.6	1.6550	1.1692	.9151	.854	.718	34.674	47.319	1.619
4.951	73.0	.7	1.6590	1.1745	.8918	.894	.721	32.615	48.575	.975
5.085	80.7	.8	1.6640	1.1940	.8073	.906	.723	32.721	49.256	.356
5.230	89.1	.9	1.6560	1.2370	.6541	.853	.714	38.299	49.926	.126

ELEMENT DATA AT TRAILING EDGE

STREAM LINE	PRESSURE RATIO	TEMPERATURE RATIO	EFFICIENCY	DIFFUSION FACTOR	TOTAL PRESSURE LOSS COEFFICIENT
0.1	1.7869	1.1848	0.976	0.372	0.056
.2	1.6828	1.1661	.965	.327	.061
.3	1.6487	1.1614	.952	.298	.072
.4	1.6759	1.1668	.953	.347	.062
.5	1.6580	1.1654	.940	.303	.074
.6	1.6630	1.1681	.931	.301	.080
.7	1.6710	1.1734	.911	.282	.101
.8	1.6817	1.1917	.835	.296	.196
.9	1.6832	1.2332	.688	.382	.413

TABLE XIII.—Continued. ROTOR 1 BLADE ELEMENT DATA

[Plenum pressure, 101 325.04 N/m²; plenum temperature, 288.15 K.]

(b) Mass flow ratio, 0.95; speed, 100 percent design

ROTOR LEADING EDGE

RADIUS (CM)	% SPAN FROM HUB	STREAM LINE	TOTAL PRESSURE/ PLENUM TOTAL PRESSURE (P'/P'_0)	TOTAL TEMPERATURE/ PLENUM TOTAL TEMPERATURE (T'/T'_0)	RELATIVE CRITICAL VELOCITY RATIO (W/W_{cr})	ABSOLUTE CRITICAL VELOCITY RATIO (V/V_{cr})	ABSOLUTE FLOW ANGLE (α)	RELATIVE FLOW ANGLE (β)	INCIDENCE ANGLE
2.747	20.7	0.1	1.0000	1.0000	0.706	0.339	0.000	62.385	10.385
3.144	35.6	.2	.9990		.795	.375		63.180	10.180
3.460	47.5	.3	.9990		.868	.414		63.077	9.377
3.725	57.4	.4	.9975		.929	.450		62.857	8.857
3.955	66.1	.5	.9966		.980	.480		62.756	8.456
4.162	73.9	.6	.9952		1.027	.512		62.426	7.426
4.351	80.9	.7	.9919		1.063	.525		62.865	7.165
4.527	87.5	.8	.9900	1.0010	1.100	.549		62.746	6.446
4.691	93.7	.9	.9829	1.0019	1.128	.559		63.155	6.155

ROTOR TRAILING EDGE

RADIUS (CM)	% SPAN FROM HUB	STREAM LINE	TOTAL PRESSURE/ PLENUM TOTAL PRESSURE (P'/P'_0)	TOTAL TEMPERATURE/ PLENUM TOTAL TEMPERATURE (T'/T'_0)	EFFICIENCY REFERENCED TO PLENUM CONDITIONS	RELATIVE CRITICAL VELOCITY RATIO (W/W_{cr})	ABSOLUTE CRITICAL VELOCITY RATIO (V/V_{cr})	ABSOLUTE FLOW ANGLE (α)	RELATIVE FLOW ANGLE (β)	DEVIATION ANGLE
3.940	14.3	0.1	1.8520	1.1931	0.9972	0.579	0.798	50.160	24.869	2.369
4.148	26.4	.2	1.7620	1.1808	.9717	.607	.725	48.466	36.566	6.766
4.335	37.2	.3	1.7030	1.1765	.9309	.669	.675	44.776	44.194	8.894
4.506	47.1	.4	1.7330	1.1840	.9246	.684	.690	45.586	44.97[illegible]	4.971
4.666	56.4	.5	1.7390	1.1859	.9213	.708	.689	45.408	46.983	3.683
4.814	65.0	.6	1.7390	1.1879	.9116	.757	.684	42.811	48.940	3.240
4.951	73.0	.7	1.7460	1.1950	.8852	.796	.685	40.780	50.090	2.490
5.085	80.7	.8	1.7560	1.2272	.7682	.783	.689	42.974	50.497	1.597
5.230	89.1	.9	1.7710	1.2525	.7026	.654	.692	56.245	53.820	4.020

ELEMENT DATA AT TRAILING EDGE

STREAM LINE	PRESSURE RATIO	TEMPERATURE RATIO	EFFICIENCY	DIFFUSION FACTOR	TOTAL PRESSURE LOSS COEFFICIENT
0.1	1.8520	1.1931	0.997	0.416	0.007
.2	1.7639	1.1808	.974	.429	.052
.3	1.7048	1.1765	.933	.383	.113
.4	1.7373	1.1840	.929	.424	.107
.5	1.7450	1.1859	.927	.435	.099
.6	1.7474	1.1879	.920	.407	.103
.7	1.7603	1.1950	.899	.385	.128
.8	1.7738	1.2260	.787	.428	.291
.9	1.8018	1.2501	.733	.607	.342

TABLE XIII.—Continued. ROTOR 1 BLADE ELEMENT DATA

[Plenum pressure, 101 325.04 N/m^2; plenum temperature, 288.15 K.]

(c) Mass flow ratio, 0.88; speed, 100 percent design

ROTOR LEADING EDGE

RADIUS (CM)	% SPAN FROM HUB	STREAM LINE	TOTAL PRESSURE/ PLENUM TOTAL PRESSURE (P'/P'_0)	TOTAL TEMPERATURE/ PLENUM TOTAL TEMPERATURE (T'/T'_0)	RELATIVE CRITICAL VELOCITY RATIO (W/W_{cr})	ABSOLUTE CRITICAL VELOCITY RATIO (V/V_{cr})	ABSOLUTE FLOW ANGLE (α)	RELATIVE FLOW ANGLE (β)	INCIDENCE ANGLE
2.747	20.7	0.1	0.9990	1.0019	0.686	0.293	0.000	65.626	13.626
3.144	35.6	.2	.9980		.774	.326		66.252	13.252
3.460	47.5	.3	.9980		.845	.359		66.212	12.512
3.725	57.4	.4	.9971		.904	.392		65.908	11.908
3.955	66.1	.5	.9957		.955	.421		65.688	11.388
4.162	73.9	.6	.9942		1.000	.447		65.499	10.499
4.351	80.9	.7	.9923		1.035	.458		65.889	10.189
4.527	87.5	.8	.9871	1.0027	1.068	.471		66.129	9.829
4.691	93.7	.9	.9848	1.0040	1.099	.485		66.271	9.271

ROTOR TRAILING EDGE

RADIUS (CM)	% SPAN FROM HUB	STREAM LINE	TOTAL PRESSURE/ PLENUM TOTAL PRESSURE (P'/P'_0)	TOTAL TEMPERATURE/ PLENUM TOTAL TEMPERATURE (T'/T'_0)	EFFICIENCY REFERENCED TO PLENUM CONDITIONS	RELATIVE CRITICAL VELOCITY RATIO (W/W_{cr})	ABSOLUTE CRITICAL VELOCITY RATIO (V/V_{cr})	ABSOLUTE FLOW ANGLE (α)	RELATIVE FLOW ANGLE (β)	DEVIATION ANGLE
3.940	14.3	0.1	1.8810	1.2010	0.9843	0.555	0.828	52.703	20.570	-1.930
4.148	26.4	.2	1.8000	1.1892	.9665	.614	.761	48.372	32.885	3.085
4.335	37.2	.3	1.7510	1.1806	.9611	.655	.719	46.342	40.214	4.914
4.506	47.1	.4	1.7610	1.1900	.9237	.666	.717	47.153	42.531	2.531
4.666	56.4	.5	1.7560	1.1920	.9090	.684	.707	47.451	45.488	2.189
4.814	65.0	.6	1.7570	1.1990	.8780	.718	.699	46.152	47.683	1.983
4.951	73.0	.7	1.7640	1.2200	.8003	.731	.696	46.223	49.012	1.412
5.085	80.7	.8	1.7720	1.2585	.6870	.698	.695	49.955	50.187	1.287
5.230	89.1	.9	1.7830	1.2755	.6522	.658	.692	55.261	52.990	3.190

ELEMENT DATA AT TRAILING EDGE

STREAM LINE	PRESSURE RATIO	TEMPERATURE RATIO	EFFICIENCY	DIFFUSION FACTOR	TOTAL PRESSURE LOSS COEFFICIENT
0.1	1.8830	1.1987	0.997	0.460	0.007
.2	1.8036	1.1869	.982	.417	.038
.3	1.7545	1.1783	.977	.406	.039
.4	1.7662	1.1877	.940	.443	.093
.5	1.7637	1.1897	.928	.459	.102
.6	1.7672	1.1967	.898	.447	.138
.7	1.7776	1.2176	.821	.455	.253
.8	1.7951	1.2551	.713	.517	.440
.9	1.8106	1.2704	.684	.588	.467

TABLE XIII.—Concluded. ROTOR 1 BLADE ELEMENT DATA

[Plenum pressure, 101 325.04 N/m^2; plenum temperature, 288.15 K.]

(d) Mass flow ratio, 0.77; speed, 80 percent design

ROTOR LEADING EDGE

RADIUS (CM)	% SPAN FROM HUB	STREAM LINE	TOTAL PRESSURE/ PLENUM TOTAL PRESSURE (P'/P'_0)	TOTAL TEMPERATURE/ PLENUM TOTAL TEMPERATURE (T'/T'_0)	RELATIVE CRITICAL VELOCITY RATIO (W/W_{cr})	ABSOLUTE CRITICAL VELOCITY RATIO (V/V_{cr})	ABSOLUTE FLOW ANGLE (α)	RELATIVE FLOW ANGLE (β)	INCIDENCE ANGLE
2.747	20.7	0.1	1.0010	1.0000	0.567	0.260	0.000	63.326	11.326
3.144	35.6	.2	1.0010		.642	.292		63.806	10.806
3.460	47.5	.3	1.0000		.702	.321		63.815	10.115
3.725	57.4	.4	1.0000		.754	.350		63.509	9.509
3.955	66.1	.5	.9990		.796	.370		63.605	9.305
4.162	73.9	.6	.9980		.837	.396		63.237	8.237
4.351	80.9	.7	.9980		.869	.409		63.514	7.814
4.527	87.5	.8	.9952	1.0010	.900	.426		63.455	7.155
4.691	93.7	.9	.9909	1.0019	.924	.429		64.091	7.091

ROTOR TRAILING EDGE

RADIUS (CM)	% SPAN FROM HUB	STREAM LINE	TOTAL PRESSURE/ PLENUM TOTAL PRESSURE (P'/P'_0)	TOTAL TEMPERATURE/ PLENUM TOTAL TEMPERATURE (T'/T'_0)	EFFICIENCY REFERENCED TO PLENUM CONDITIONS	RELATIVE CRITICAL VELOCITY RATIO (W/W_{cr})	ABSOLUTE CRITICAL VELOCITY RATIO (V/V_{cr})	ABSOLUTE FLOW ANGLE (α)	RELATIVE FLOW ANGLE (β)	DEVIATION ANGLE
3.940	14.3	0.1	1.4870	1.1221	0.9832	0.456	0.669	52.017	22.940	0.440
4.148	26.4	.2	1.4390	1.1125	.9742	.518	.611	46.743	35.282	5.482
4.335	37.2	.3	1.4150	1.1108	.9411	.562	.581	43.845	41.652	6.352
4.506	47.1	.4	1.4210	1.1122	.9412	.583	.585	43.751	43.525	3.525
4.666	56.4	.5	1.4170	1.1130	.9267	.619	.578	41.802	46.100	2.800
4.814	65.0	.6	1.4180	1.1151	.9117	.651	.579	40.308	47.684	1.984
4.951	73.0	.7	1.4170	1.1189	.8807	.683	.577	38.463	49.177	1.577
5.085	80.7	.8	1.4150	1.1251	.8335	.627	.574	46.216	50.968	2.068
5.230	89.1	.9	1.4140	1.1395	.7459	.644	.572	45.962	52.234	2.434

ELEMENT DATA AT TRAILING EDGE

STREAM LINE	PRESSURE RATIO	TEMPERATURE RATIO	EFFICIENCY	DIFFUSION FACTOR	TOTAL PRESSURE LOSS COEFFICIENT
0.1	1.4855	1.1221	0.981	0.455	0.047
.2	1.4376	1.1125	.971	.393	.051
.3	1.4150	1.1108	.941	.370	.088
.4	1.4210	1.1122	.941	.394	.077
.5	1.4185	1.1130	.930	.377	.084
.6	1.4208	1.1151	.917	.369	.092
.7	1.4198	1.1189	.886	.351	.124
.8	1.4219	1.1240	.853	.469	.146
.9	1.4270	1.1373	.779	.464	.235

TABLE XIV.—ROTOR 2 BLADE ELEMENT DATA

[Plenum pressure, 101 325.04 N/m^2; plenum temperature, 288.15 K.]

(a) Mass flow ratio, 1.0; speed, 100 percent design

ROTOR LEADING EDGE

RADIUS (CM)	% SPAN FROM HUB	STREAM LINE	TOTAL PRESSURE/ PLENUM TOTAL PRESSURE (P'/P'_0)	TOTAL TEMPERATURE/ PLENUM TOTAL TEMPERATURE (T'/T'_0)	RELATIVE CRITICAL VELOCITY RATIO (W/W_{cr})	ABSOLUTE CRITICAL VELOCITY RATIO (V/V_{cr})	ABSOLUTE FLOW ANGLE (α)	RELATIVE FLOW ANGLE (β)	INCIDENCE ANGLE
4.609	14.1	0.1	1.7850	1.1859	0.735	0.757	43.069	40.993	-4.007
4.803	26.8	.2	1.6810	1.1672	.818	.711	37.829	47.430	1.230
4.978	38.3	.3	1.6470	1.1625	.880	.695	34.114	50.479	3.179
5.134	48.5	.4	1.6710	1.1679	.896	.718	35.026	50.239	1.939
5.277	57.9	.5	1.6500	1.1665	.954	.717	31.308	51.799	2.799
5.408	66.5	.6	1.6550	1.1692	.987	.727	30.009	52.302	2.502
5.526	74.2	.7	1.6590	1.1745	1.017	.729	28.506	53.094	2.794
5.639	81.6	.8	1.6640	1.1940	1.014	.716	29.495	54.197	3.197
5.759	89.5	.9	1.6560	1.2370	.949	.684	35.940	55.899	4.099

ROTOR TRAILING EDGE

RADIUS (CM)	% SPAN FROM HUB	STREAM LINE	TOTAL PRESSURE/ PLENUM TOTAL PRESSURE (P'/P'_0)	TOTAL TEMPERATURE/ PLENUM TOTAL TEMPERATURE (T'/T'_0)	EFFICIENCY REFERENCED TO PLENUM CONDITIONS	RELATIVE CRITICAL VELOCITY RATIO (W/W_{cr})	ABSOLUTE CRITICAL VELOCITY RATIO (V/V_{cr})	ABSOLUTE FLOW ANGLE (α)	RELATIVE FLOW ANGLE (β)	DEVIATION ANGLE
5.611	13.0	0.1	3.0800	1.4020	0.9430	0.697	1.002	54.042	27.447	8.947
5.701	22.1	.2	3.0175	1.3800	.9763	.706	.977	53.877	31.624	7.024
5.791	31.3	.3	2.8300	1.3590	.9641	.756	.919	50.998	38.280	8.580
5.879	40.2	.4	2.7350	1.3520	.9462	.807	.881	48.008	42.314	8.314
5.963	48.8	.5	2.6980	1.3578	.9164	.817	.860	47.744	44.574	6.774
6.049	57.6	.6	2.6775	1.3750	.8666	.814	.842	48.347	46.317	5.317
6.138	66.6	.7	2.6875	1.4045	.8069	.792	.836	50.298	47.218	3.418
6.236	76.5	.8	2.7575	1.4450	.7555	.762	.848	52.608	46.835	.335
6.341	87.3	.9	2.8200	1.4620	.7462	.714	.856	56.802	47.921	- .279

ELEMENT DATA AT TRAILING EDGE

STREAM LINE	PRESSURE RATIO	TEMPERATURE RATIO	EFFICIENCY	DIFFUSION FACTOR	TOTAL PRESSURE LOSS COEFFICIENT
0.1	1.7255	1.1822	0.926	0.198	0.183
.2	1.7951	1.1823	.998	.293	.004
.3	1.7183	1.1690	.990	.270	.016
.4	1.6367	1.1576	.959	.187	.063
.5	1.6351	1.1640	.920	.233	.111
.6	1.6178	1.1760	.837	.261	.228
.7	1.6199	1.1958	.755	.316	.351
.8	1.6571	1.2102	.739	.356	.393
.9	1.7029	1.1819	.903	.373	.138

TABLE XIV.—Continued: ROTOR 2 BLADE ELEMENT DATA

[Plenum pressure, 101 325.04 N/m²; plenum temperature, 288.15 K.]

(b) Mass flow ratio, 0.95; speed, 100 percent design

ROTOR LEADING EDGE

RADIUS (CM)	% SPAN FROM HUB	STREAM LINE	TOTAL PRESSURE/ PLENUM TOTAL PRESSURE (P'/P'_0)	TOTAL TEMPERATURE/ PLENUM TOTAL TEMPERATURE (T'/T'_0)	RELATIVE CRITICAL VELOCITY RATIO (W/W_{cr})	ABSOLUTE CRITICAL VELOCITY RATIO (V/V_{cr})	ABSOLUTE FLOW ANGLE (α)	RELATIVE FLOW ANGLE (β)	INCIDENCE ANGLE
4.609	14.1	0.1	1.8520	1.1931	0.704	0.729	45.143	42.874	-2.126
4.803	26.8	.2	1.7620	1.1808	.752	.684	43.271	48.994	2.794
4.978	38.3	.3	1.7030	1.1765	.815	.648	39.701	53.221	5.921
5.134	48.5	.4	1.7330	1.1840	.833	.673	40.042	52.820	4.520
5.277	57.9	.5	1.7390	1.1859	.860	.682	39.493	53.351	4.351
5.408	66.5	.6	1.7390	1.1879	.902	.684	37.239	54.220	4.420
5.526	74.2	.7	1.7460	1.1950	.933	.689	35.590	54.684	4.384
5.639	81.6	.8	1.7560	1.2272	.909	.679	38.586	55.598	4.598
5.759	89.5	.9	1.7710	1.2525	.789	.663	51.987	59.375	7.575

ROTOR TRAILING EDGE

RADIUS (CM)	% SPAN FROM HUB	STREAM LINE	TOTAL PRESSURE/ PLENUM TOTAL PRESSURE (P'/P'_0)	TOTAL TEMPERATURE/ PLENUM TOTAL TEMPERATURE (T'/T'_0)	EFFICIENCY REFERENCED TO PLENUM CONDITIONS	RELATIVE CRITICAL VELOCITY RATIO (W/W_{cr})	ABSOLUTE CRITICAL VELOCITY RATIO (V/V_{cr})	ABSOLUTE FLOW ANGLE (α)	RELATIVE FLOW ANGLE (β)	DEVIATION ANGLE
5.611	13.0	0.1	3.2120	1.4103	0.9644	0.650	0.999	56.686	26.947	8.447
5.701	22.1	.2	3.1220	1.3910	.9832	.658	.969	56.579	31.789	7.189
5.791	31.3	.3	2.9120	1.3722	.9596	.704	.904	54.158	39.251	9.551
5.879	40.2	.4	2.8230	1.3718	.9284	.744	.867	52.073	43.074	9.074
5.963	48.8	.5	2.8060	1.3837	.8935	.762	.851	51.299	44.879	7.079
6.049	57.6	.6	2.8170	1.4015	.8576	.759	.844	51.982	46.026	5.026
6.138	66.6	.7	2.8570	1.4320	.8097	.737	.847	53.842	46.436	2.636
6.236	76.5	.8	2.9250	1.4645	.7726	.699	.855	56.812	46.784	.284
6.341	87.3	.9	2.9840	1.4845	.7568	.668	.861	59.705	48.063	- .137

ELEMENT DATA AT TRAILING EDGE

STREAM LINE	PRESSURE RATIO	TEMPERATURE RATIO	EFFICIENCY	DIFFUSION FACTOR	TOTAL PRESSURE LOSS COEFFICIENT
0.1	1.7343	1.1821	0.936	0.247	0.165
.2	1.7718	1.1780	.997	.295	.005
.3	1.7099	1.1663	.996	.277	.007
.4	1.6290	1.1586	.943	.212	.097
.5	1.6136	1.1668	.878	.203	.211
.6	1.6199	1.1798	.822	.251	.300
.7	1.6363	1.1983	.762	.314	.403
.8	1.6657	1.1934	.812	.348	.318
.9	1.6849	1.1852	.868	.260	.295

TABLE XIV.—Continued. ROTOR 2 BLADE ELEMENT DATA

[Plenum pressure, 101 325.04 N/m^2; plenum temperature, 288.15 K.]

(c) Mass flow ratio, 0.88; speed, 100 percent design

ROTOR LEADING EDGE

RADIUS (CM)	% SPAN FROM HUB	STREAM LINE	TOTAL PRESSURE/ PLENUM TOTAL PRESSURE (P'/P'_0)	TOTAL TEMPERATURE/ PLENUM TOTAL TEMPERATURE (T'/T'_0)	RELATIVE CRITICAL VELOCITY RATIO (W/W_{cr})	ABSOLUTE CRITICAL VELOCITY RATIO (V/V_{cr})	ABSOLUTE FLOW ANGLE (α)	RELATIVE FLOW ANGLE (β)	INCIDENCE ANGLE
4.609	14.1	0.1	1.8810	1.2010	0.660	0.739	48.779	41.819	-3.181
4.803	26.8	.2	1.8000	1.1892	.730	.693	45.159	48.173	1.973
4.978	38.3	.3	1.7510	1.1806	.783	.666	42.825	52.041	4.741
5.134	48.5	.4	1.7610	1.1900	.797	.671	43.431	53.021	4.721
5.277	57.9	.5	1.7560	1.1920	.817	.668	43.554	54.484	5.484
5.408	66.5	.6	1.7570	1.1990	.847	.666	42.348	55.452	5.652
5.526	74.2	.7	1.7640	1.2200	.857	.668	42.389	55.919	5.619
5.639	81.6	.8	1.7720	1.2585	.819	.659	46.724	57.345	6.345
5.759	89.5	.9	1.7830	1.2755	.767	.637	54.184	61.476	9.676

ROTOR TRAILING EDGE

RADIUS (CM)	% SPAN FROM HUB	STREAM LINE	TOTAL PRESSURE/ PLENUM TOTAL PRESSURE (P'/P'_0)	TOTAL TEMPERATURE/ PLENUM TOTAL TEMPERATURE (T'/T'_0)	EFFICIENCY REFERENCED TO PLENUM CONDITIONS	RELATIVE CRITICAL VELOCITY RATIO (W/W_{cr})	ABSOLUTE CRITICAL VELOCITY RATIO (V/V_{cr})	ABSOLUTE FLOW ANGLE (α)	RELATIVE FLOW ANGLE (β)	DEVIATION ANGLE
5.611	13.0	0.1	3.2330	1.4118	0.9672	0.585	0.976	60.246	28.757	10.257
5.701	22.1	.2	3.1220	1.3930	.9782	.611	.942	59.291	34.351	9.751
5.791	31.3	.3	2.9290	1.3822	.9404	.646	.882	57.946	41.453	11.753
5.879	40.2	.4	2.8370	1.3848	.9019	.682	.846	56.311	45.272	11.272
5.963	48.8	.5	2.8160	1.3985	.8638	.697	.831	55.909	47.069	9.269
6.049	57.6	.6	2.8360	1.4195	.8270	.692	.828	56.727	48.012	7.012
6.138	66.6	.7	2.8880	1.4545	.7788	.681	.835	57.625	47.825	4.025
6.236	76.5	.8	2.9880	1.4918	.7466	.652	.857	59.694	47.003	.503
6.341	87.3	.9	3.0680	1.5235	.7212	.610	.869	62.980	47.850	- .350

ELEMENT DATA AT TRAILING EDGE

STREAM LINE	PRESSURE RATIO	TEMPERATURE RATIO	EFFICIENCY	DIFFUSION FACTOR	TOTAL PRESSURE LOSS COEFFICIENT
0.1	1.7188	1.1755	0.954	0.289	0.132
.2	1.7344	1.1714	.994	.330	.013
.3	1.6728	1.1708	.927	.314	.144
.4	1.6110	1.1637	.892	.252	.208
.5	1.6036	1.1732	.834	.243	.327
.6	1.6141	1.1839	.797	.283	.391
.7	1.6372	1.1922	.787	.312	.415
.8	1.6862	1.1854	.868	.325	.264
.9	1.7207	1.1944	.863	.340	.325

TABLE XIV.—Concluded. ROTOR 2 BLADE ELEMENT DATA

[Plenum pressure, 101 325.04 N/m^2; plenum temperature, 288.15 K.]

(d) Mass flow ratio, 0.77; speed, 80 percent design

ROTOR LEADING EDGE

RADIUS (CM)	% SPAN FROM HUB	STREAM LINE	TOTAL PRESSURE/ PLENUM TOTAL PRESSURE (P'/P'_0)	TOTAL TEMPERATURE/ PLENUM TOTAL TEMPERATURE (T'/T'_0)	RELATIVE CRITICAL VELOCITY RATIO (W/W_{cr})	ABSOLUTE CRITICAL VELOCITY RATIO (V/V_{cr})	ABSOLUTE FLOW ANGLE (α)	RELATIVE FLOW ANGLE (β)	INCIDENCE ANGLE
4.609	14.1	0.1	1.4870	1.1221	0.566	0.612	46.613	41.820	-3.180
4.803	26.8	.2	1.4390	1.1125	.640	.581	41.408	47.406	1.206
4.978	38.3	.3	1.4150	1.1108	.686	.562	38.594	50.874	3.574
5.134	48.5	.4	1.4210	1.1122	.713	.577	37.936	51.036	2.736
5.277	57.9	.5	1.4170	1.1130	.747	.579	36.096	52.158	3.158
5.408	66.5	.6	1.4180	1.1151	.778	.588	34.542	52.542	2.742
5.526	74.2	.7	1.4170	1.1189	.804	.589	33.095	53.332	3.032
5.639	81.6	.8	1.4150	1.1251	.816	.581	32.994	54.570	3.570
5.759	89.5	.9	1.4140	1.1395	.758	.571	40.803	56.128	4.328

ROTOR TRAILING EDGE

RADIUS (CM)	% SPAN FROM HUB	STREAM LINE	TOTAL PRESSURE/ PLENUM TOTAL PRESSURE (P'/P'_0)	TOTAL TEMPERATURE/ PLENUM TOTAL TEMPERATURE (T'/T'_0)	EFFICIENCY REFERENCED TO PLENUM CONDITIONS	RELATIVE CRITICAL VELOCITY RATIO (W/W_{cr})	ABSOLUTE CRITICAL VELOCITY RATIO (V/V_{cr})	ABSOLUTE FLOW ANGLE (α)	RELATIVE FLOW ANGLE (β)	DEVIATION ANGLE
5.611	13.0	0.1	2.1222	1.2500	0.9592	0.593	0.856	53.397	26.902	8.402
5.701	22.1	.2	2.1151	1.2410	.9903	.613	.843	52.364	29.988	5.388
5.791	31.3	.3	2.0149	1.2250	.9850	.638	.790	50.707	36.815	7.115
5.879	40.2	.4	1.9620	1.2190	.9696	.686	.757	47.427	41.100	7.100
5.963	48.8	.5	1.9341	1.2200	.9429	.701	.735	46.688	43.772	5.972
6.049	57.6	.6	1.9332	1.2250	.9211	.710	.731	46.602	44.839	3.839
6.138	66.6	.7	1.9398	1.2400	.8683	.697	.720	48.216	46.339	2.539
6.236	76.5	.8	1.9549	1.2601	.8117	.660	.710	51.915	48.145	1.645
6.341	87.3	.9	1.9639	1.2680	.7937	.625	.701	56.018	50.804	2.604

ELEMENT DATA AT TRAILING EDGE

STREAM LINE	PRESSURE RATIO	TEMPERATURE RATIO	EFFICIENCY	DIFFUSION FACTOR	TOTAL PRESSURE LOSS COEFFICIENT
0.1	1.4271	1.1140	0.938	0.115	0.149
.2	1.4698	1.1155	1.007	.204	-.013
.3	1.4240	1.1028	1.034	.208	-.049
.4	1.3807	1.0960	1.005	.137	-.007
.5	1.3649	1.0961	.967	.150	.040
.6	1.3633	1.0985	.939	.174	.070
.7	1.3689	1.1083	.867	.226	.157
.8	1.3816	1.1200	.806	.296	.242
.9	1.3889	1.1127	.873	.276	.174

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16. Abstract
A conical-flow compressor stage with a large radius change through the rotor was tested at three values of rotor-tip clearance. The stage had a tandem rotor and a tandem stator. Peak efficiency at design speed was 0.774 at a pressure ratio of 2.613. The rotor was tested without the stator, and detailed survey data were obtained for each rotor blade row. Overall peak rotor efficiency was 0.871 at a pressure ratio of 2.952.

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